DRAINAGE STUDY
FOR
UPPER MANKLIN CREEK WATERSHED
MARYLAND ROUTE 90 - MARYLAND ROUTE 589
WORCESTER COUNTY, MARYLAND

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MARYLAND ROUTE 90 - MARYLAND ROUTE 589
WORCESTER COUNTY, MARYLAND

Maryland, Coastal Zone Management Program

CONSULTING ENGINEERS AND SURVEYORS
Andrews, Miller & Assoc., Inc.

DONALD E. ANDREWS, P.E.
HAROLD M. MILLER, JR., P.E.

ADDENDUM NO. 1

January 4, 1989

Pursuant to presentation of this Study to the Worcester County Commissioners on January 3, 1989, the Commissioners requested the following items be added to the report:

1. A recommendation that proposed stormwater management designs in the Study Area be reviewed with more scrutiny than projects in the past, specifically in regard to adequate sizing of structures and drainage ways.

2. A recommendation that stormwater management performance bond amounts, as required by Section 2-107 of the Worcester County Stormwater Management Ordinance, be reviewed in detail to assure that the amount of obligation is sufficient to insure corrective action on the part of owners/developers with faulty or insufficient stormwater facilities.

3. A notation that at least one of the problem sites identified (excess drainage to the Martin Groff property) has undergone corrective action since the time of the field investigations (August 1988); questions relative to the number of sites which have completed remedial work should be directed to Jennings Quillen, Worcester County Building Inspector, telephone (301) 632-1200.

4. A notation that the slides from the field investigations, as referenced in the text of the Study, will be maintained at the Worcester County Planning and Permits Department.

5. A notation that the recommendation made in Section 6.1.C.6 of this Study relative to the requirement of "as-built" plans for all stormwater management and drainage facilities is mentioned in Section 2-107 of the Worcester County Stormwater Management Ordinance as a prerequisite for the release of stormwater management performance bonds; and further, a recommendation that the requirements of the existing statute be more stringently enforced.

In addition, the following errata has been reported:

Page 20, paragraph one: "whcih" should be "which".

END OF ADDENDUM NO. 1

JHWjr/pjv

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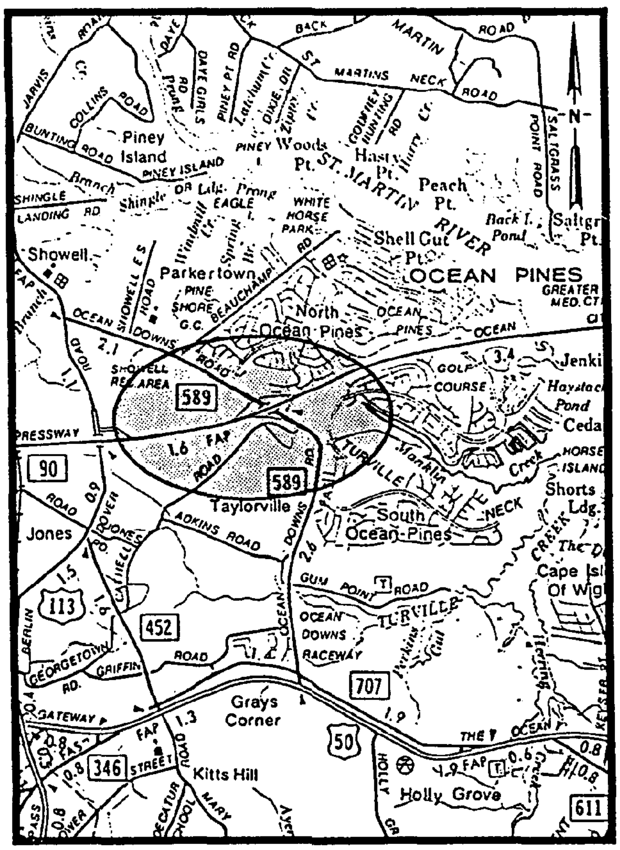
WORCESTER COUNTY, MARYLAND



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NOVEMBER 1988

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DRAINAGE STUDY

FOR

UPPER MANKLIN CREEK WATERSHED

was made jointly by

Maryland Department of Natural Resources
Water Resources Administration

and

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Office of Coastal Resources Management

We would like to thank the Worcester County Drainage Steering Committee for their help and guidance in gathering data and preparation of this document.

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EXECUTIVE SUMMARY

The Upper Manklin Creek Watershed is an area in northeastern Worcester County which has been identified as a drainage/stormwater management problem area due to existing and potential development. The area is located at the intersection of two major traffic routes - Md. Route 90 and Md. Route 589, and includes portions of Ocean Pines, a major residential development, and an existing commercial area centered on the Pines Plaza Shopping Center. Due to its prime location, the area is expected to be under extreme development pressure in the future.

This Study was undertaken to develop a catalog of existing drainage and stormwater problems in the area, and to identify regional practices which could be implemented to prevent future exacerbation of the problems. One major hindrance to preparing an extremely thorough plan of action was the lack of contour and elevation data for the area, and insufficient budget to include an aerial topography of the area into the Study. As a result, many of the recommendations are general in nature, but include details specific enough to establish an effective and implementable plan for future development.

Site investigations of fourteen properties were conducted in August 1988. Several of the sites need remedial measures to improve the existing drainage patterns. These recommendations can be found in the "Site Assessment Data" found in Appendix 1.

Stormwater management projections were made using standard rates of growth for developed areas of Worcester County, and it was discovered that by the year 2000 an additional 300 cfs of runoff could be expected, nearly doubling existing flows. These results are explained in Section 4, with pertinent calculations contained in Appendix 2.

Regional recommendations are made to generally include the use of best management practices within the identified watershed, with particular emphasis on the use of existing or newly constructed non-tidal wetlands as stormwater receivers, and wet ponds excavated down into permeable soil strata. It is also suggested that the large capacity drainage ditches located on the north and south sides of Md. Route 90 could be used as positive outlets for managed stormwater flows. Correction of existing drainage problems in accordance with the site assessment recommendations, and creation of a drainage district wherein the property owners would be responsible for maintenance of all ditches and drainage facilities is suggested.

Finally, a series of regulatory guidelines is suggested in Chapter 6 of the Study. Recommendations here include the formation of a drainage district with stiffer requirements for stormwater management than presently contained in the Worcester

County Ordinance. Specific actions include the protection of non-tidal wetlands for use as stormwater receivers, an order of preferred implementation for stormwater management techniques beginning ideally with the infiltration of the two year post-development storm event, and various details which should be required of all drainage and stormwater plans including a maximum size of continuous impervious pavement, a specified minimum ditch section, storage of the ten year post-development storm with a two year pre-development release rate for conventional dry detention ponds, increased bonding and maintenance agreement requirements, and submittal of as-built plans, using field generated data, for all stormwater and drainage facilities to assure compliance with approved plans.

1. INTRODUCTION

A. Purpose and Scope

Worcester County officials have pinpointed several areas within the County as potential "prime development" areas in accordance with the draft Worcester County Comprehensive Development Plan, July, 1988. These areas, for various reasons, are currently developing , or are projected to develop, rapidly. This increased development could cause major drainage or stormwater management problems in the future unless guidelines for additional governmental regulation above the existing Worcester County Stormwater Management Ordinance (P.L. No. 84-6) are provided.

One of these areas is known as the Upper Manklin Creek Watershed Area. This area has already experienced a significant amount of commercial and high density residential development.

This drainage study provides a document of existing drainage or stormwater management problems in this area of Worcester County. Problem areas were identified with the help of the following Worcester County Agencies: Soil Conservation Service; Soil Conservation District; Roads Department; County Engineer; and Planning and Permits. This report consists of: the findings of field investigations,investigation of the effects of development under current and proposed zoning, and land use designations, based on the Comprehensive Development Plan, currently being updated; possible solutions to the existing drainage problems; preventive measures to ward off additional problems or an increased magnitude of existing problems; and suggested guidelines for applicable governmental agencies to use in developing policy on drainage problems in commercial or high development areas.

B. General Information

Commercial development has a profound impact on stormwater runoff by increasing quantity and concentration of flow, and by reducing the natural time of concentration. Likewise, stormwater runoff has a similar relationship with water quality due to the contaminants known to be carried in runoff waters. These adverse impacts have made it necessary to incorporate the use of "Best Management Practices" into the overall development plan for a specified area. Most of these practices involve extra detention, retention or infiltration of stormwater runoff to increase pollutant removal and provide additional stormwater management. However, effective implementation of these practices can be designed to provide maximum pollutant removal while minimizing costs and maintenance burdens.

C. Study Area Location and Description

The +/- 1200 acre study area (see Figure 1-1) is located in northeastern Worcester County in an area known as the Upper Manklin Creek Watershed. This area is more particularly known as the Maryland Route 90 and Maryland Route 589 intersection, and surrounding area. Although the area as a whole is primarily wooded or used as agricultural fields, the corridors along Maryland Route 90 and Maryland Route 589 are rapidly developing, and slowly changing the characteristics of the watershed. The northern and eastern portion of the study area is already developed into a high density residential area. Near this residential area is a growing commercial area with a shopping center and various commercial businesses.

D. Soils

This portion of the County falls under the Fallsington, Woodstown, Sassafras association. These soils are described as "level to steep, poorly drained to well drained soils that have a subsoil dominantly of sandy clay loam". (Soil Survey of Worcester County, Maryland - U.S.D.A. - SCS 1973.)

The individual Soil Mapping units are found on Figure 1-2, and described on Table 1-1 below. These mapping units can also be classified into Hydrologic Soil Groups (HSG's). This classification groups the soils according to their minimum infiltration rate. Group "A" soils typically have infiltration rates equal to or greater than 2.41 inches per hour, group "B" soils greater than 0.52 inches per hour, group "C" soils greater than 0.17 inches per hour, and group "D" soils encompassing all those with rates less than 0.17 inches per hour.

TABLE 1-1

SOIL GROUPS

Map Symbol	Soil Name	Hydrologic Soil Group
El	Elkton Loam	D
Em	Elkton Silt Loam	D
Fa	Fallsington Sandy Loam	D
Fg	Fallsington Loam	D
FmB	Fort Mott Loamy Sand	B
Gb	Gravel and Borrow Pits	---
KsA	Klej Loamy Sand 2-5% slopes	B
LkD	Lakeland Loamy Sand 5-15% slopes	A
LmB	Lakeland Loamy Sand, Clayey Substratum 0-15% slopes	A
MdA	Matapeake Fine Sandy Loam 0-2% slopes	B
MdB	Matapeake Fine Sandy Loam 2-5% slopes	B
MoA	Matapeake Fine Sandy Loam, 0-2% slopes	C
MpA	Mattapex Loam 0-2% slopes	C
MtA	Mattapex Silt Loam 0-2% slopes	C
My	Mixed Alluvial Land	Avg. D
Pk	Pocomoke Sandy Loam	D
Pm	Pocomoke Loam	D
Pt	Portsmouth Silt Loam	D
SaA	Sassafras Sandy Loam 0-2% slopes	B
SaB2	Sassafras Sandy Loam 2-5% slopes moderately eroded	B
SaC2	Sassafras Sandy Loam 5-10% slopes moderately eroded	B
WdA	Woodstown Sandy Loam 0-2% slopes	C

TABLE 1-1

SOIL GROUPS (cont.)

Map Symbol	Soil Name	Hydrologic Soil Group
WdB	Woodstown Sandy Loam 2-5% slopes	C
WoA	Woodstown Loam 0-2% slopes	C
WoB	Woodstown Loam 2-5% slopes	C

2. **MANAGEMENT PRACTICES**

A. **Background and Purpose**

Design considerations for effective stormwater runoff management practices in a particular watershed should be based on the following guidelines:

1) Solve existing flooding problems.

2) Maximize the storage of stormwater runoff in existing natural or manmade management areas.

3) Maintain or improve the capacities of stormwater management/drainage systems in existing developed areas.

4) Prevent increased downstream flooding within the watershed.

Development of any type generally changes runoff characteristics within a watershed. This in turn also causes internal redistribution of stormwater runoff. A regional "Stormwater Management Master Plan" would be an effective way of steering the development in a particular area to permit as much development as possible, while reducing the effects of downstream flooding.

Technical solutions to stormwater management problems should be based on existing land use plans. An example of such a solution would be a regional, selfregulating, pressurized storm sewer interceptor with several branches that would accommodate existing and ultimate development without causing downstream flooding. Systems such as this would require careful thought in calculating a cost sharing and allocation formula that would best suit the financial structure of the area. The main thrust of an ideal "Stormwater Management Master Plan" would be to reduce long term capital expenditures, while reducing the hazards of flooding.

The following management practices could be used to effectively modify current drainage patterns and adequately control stormwater runoff to provide a safer, healthier environment. These practices may be used alone, but with various combinations and the adaptation of a set of guidelines for stormwater runoff control, a more efficient and long term solution may be obtained.

B. Description of Practices

1) Infiltration Basins

Infiltration basins are either natural or excavated open depressions of varying size in the ground surface for storage and infiltration of stormwater runoff. This type of management practice is best suited to control drainage areas ranging from 5 to 50 acres in size. While they require ample space and permeable soils, this type of system is the least expensive to construct per unit of water handled.

Infiltration basins have two major requirements for adequate performance. First, the soils in the vicinity must be permeable to enable the stormwater runoff to be completely drained within 3 days following the occurrence of a storm event. Second, the existing water table must be well below existing grade.

Due to the large amount of type "c" and "d" soil groups found in this area, this type of system may have limited use. Effectiveness may be increased by combining other practices such as detention basins, vegetative buffer strips and vegetated swales.

Most moderately sized commercial projects are ideal for this type of system if conditions suit. Infiltration basins can be constructed inside the buffer areas and in any open space areas that are convenient to the drainage scheme of the project.

2) **Infiltration Trenches**

Infiltration trenches are excavated trenches, generally 2 to 10 feet in depth, backfilled with stone aggregate, allowing for temporary storage of stormwater runoff in the voids between the aggregate material. Infiltration trenches usually serve an area up to about 5 acres. Permeability of the soil and depth to seasonal high water table are limiting factors for this practice.

This practice is very similar to the infiltration basin, except that infiltration trenches do not require as much surface area. However, more rigorous sediment and erosion control techniques must be incorporated into the design of the entire project to ensure that trenches do not prematurely clog.

If conditions permit, this practice is very well suited for most small sites. Although cost may be prohibitive, this system may be a "space saving" alternative to other associated practices.

3) **Dry Wells**

A dry well is very similar to an infiltration trench. A dry well is generally much smaller and has an inflow pipe. This practice is generally used to capture stormwater runoff from rooftop areas of less than 1 acre. Another use can be found in storm drain infiltration catch basins.

For any application, the site conditions must include soils that are suitable for infiltration with depth to the top of the seasonal high groundwater table.

This type of practice would be most effective when combined with other systems such as infiltration trenches or infiltration ponds. Large buildings, such as Pines Plaza Shopping Center, could incorporate this practice into the drainage scheme for the roof leaders. This would help to reduce the stormwater runoff flowing across the pavement on most large projects.

4. <u>Porous Asphalt Paving</u>

Porous asphaltic paving material and a high void aggregate base allow for rapid infiltration and temporary storage of stormwater runoff. This type of system works well when installed and maintained properly. However, when installed and maintained as per the guidelines set forth in the "Standards and Specifications for Infiltration Procedures" (DNR-WRA 1984) this practice can be very cost prohibitive.

5) <u>Vegetative Practices</u>

In these practices, various forms of vegetation are used to enhance the pollutant removal, habitat value, and appearance of the site. Although these practices are generally not capable of completely controlling the stormwater runoff and exportation of pollutants from the site, they can be used to help improve the adequacy of other management practices. Often these systems are added to existing management systems to aid in improving runoff characteristics.

6) **Grassed Swales**

Grassed swales are typically used in low density developments and as an alternative to curb and gutter. Due to the limited capacity of swales, they often must lead into storm drain inlets or holding structures to prevent erosion during large concentrated flows.

7) **Filter Strips**

Filter strips are designed specifically to accept evenly distributed, overland sheet flow. Relatively inexpensive to establish, filter strips can be incorporated into other management practices such as infiltration trenches. When constructed properly, the filter strip will remove most of the particulate pollutants, therefore reducing the clogging problem present with the use of infiltration trenches.

8) **Urban Forestry**

This practice involves either preserving trees during construction, or landscaping after the site has been developed. With careful design considerations, the cost and maintenance requirements for most urban forestry practices are quite low, while the environmental amenity value is often very high.

This type of practice generally produces 30-50% less runoff than grassed lawns. However, this practice is best suited to residential areas and large buffer areas.

9) **Extended Detention Ponds**

Depending on the quantity of stormwater runoff detained, and the time over which it is released, extended detention ponds can significantly reduce the flooding affects at the downstream outlet. This type of management practice generally require a two-stage design, whereby the top portion of the pond is to remain dry most of the time and a smaller portion of the pond near the riser is regularly inundated. Although this practice requires more maintenance, it is easily implemented in existing detention ponds.

10) **Wet Ponds**

Wet ponds, if properly sized and maintained, are an extremely effective water quality management practice. On very large, more intensively developed projects, wet ponds are most cost effective. Through careful design considerations, wet ponds can provide stormwater management, pollutant removal, and habitat improvement. However, due to maintenance and nuisance problems, wet ponds are most suited for large development sites where the general public does not come in direct contact with the pond.

11) **Borrow Pits - Commercial**

The existing borrow pits in the vicinity could be used as extended detention wet ponds. The ponds could possibly be enlarged or deepened to accommodate the additional stormwater runoff. By using water quality practices and individual retention/detention structures, the existing downstream outlet would be protected from erosive flooding.

3. SITE ASSESSMENTS

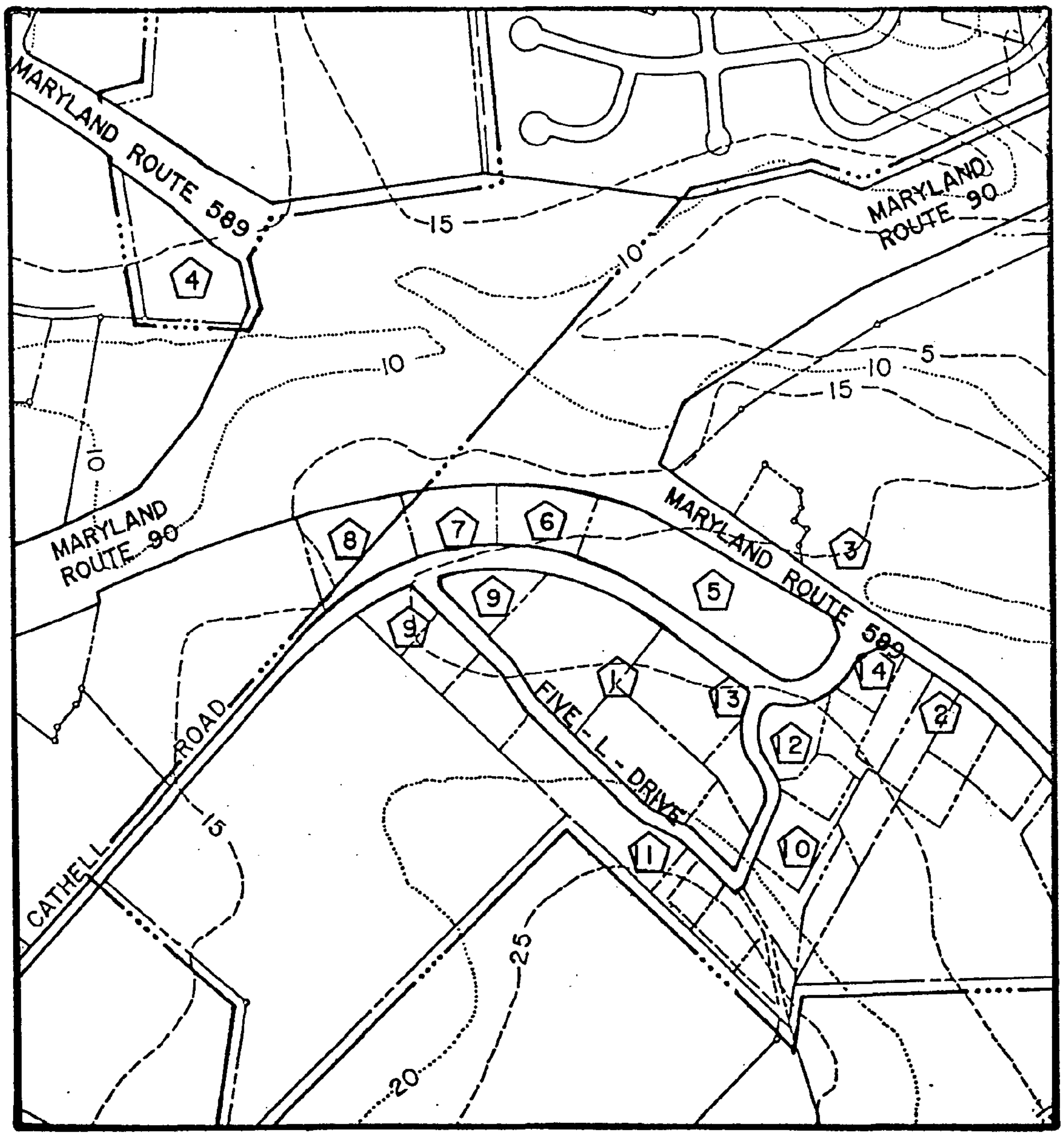
Various Worcester County officials (previously identified in Section 1 of this Report) have identified the Pines Plaza Shopping Center and the Five-L-Park area as the existing "problem area" within the study area. This area has experienced rapid growth and currently has poor drainage characteristics.

Specific sites in and around this problem area were investigated to determine what methods of drainage or stormwater management was utilized on each site. Ay drainage related problems found on site were recorded to help assess the effects of the existing development on the nearby drainage systems. Results of these field investigations were recorded on worksheets entitled "Site Assessment Data" which may be found in Appendix 1. Fourteen sites were investigated in this manner. Location of these sites are indicated on Figure 3-1. Slide photographs of the sites were taken, and a description of the slides can be found in Appendix 1.

Information contained on these worksheets includes site location and description, soil types, stormwater management and drainage measures, and a description of problems encountered along with suggested resolutions for the problems. Ten sites were found to have drainage problems resulting from poor grading, obstructed drainage ways, or lack of suitable outfalls. Four sites were found to have stormwater management related problems resulting from improperly designed, constructed, or maintained facilities. Six sites did not have any observable stormwater management measures in place. Three sites were found to be adequately drained with functioning stormwater facilities. Some of the sites experience multiple problems.

Although solutions to existing problems have been suggested within the "Site Assessment Data" format, it is possible that better solutions may result from the implementation of a regional storm drainage plan. Regional solutions will be discussed further in Section 5 of this Report.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT
LOCATION MAP



SCALE 1" = 600'

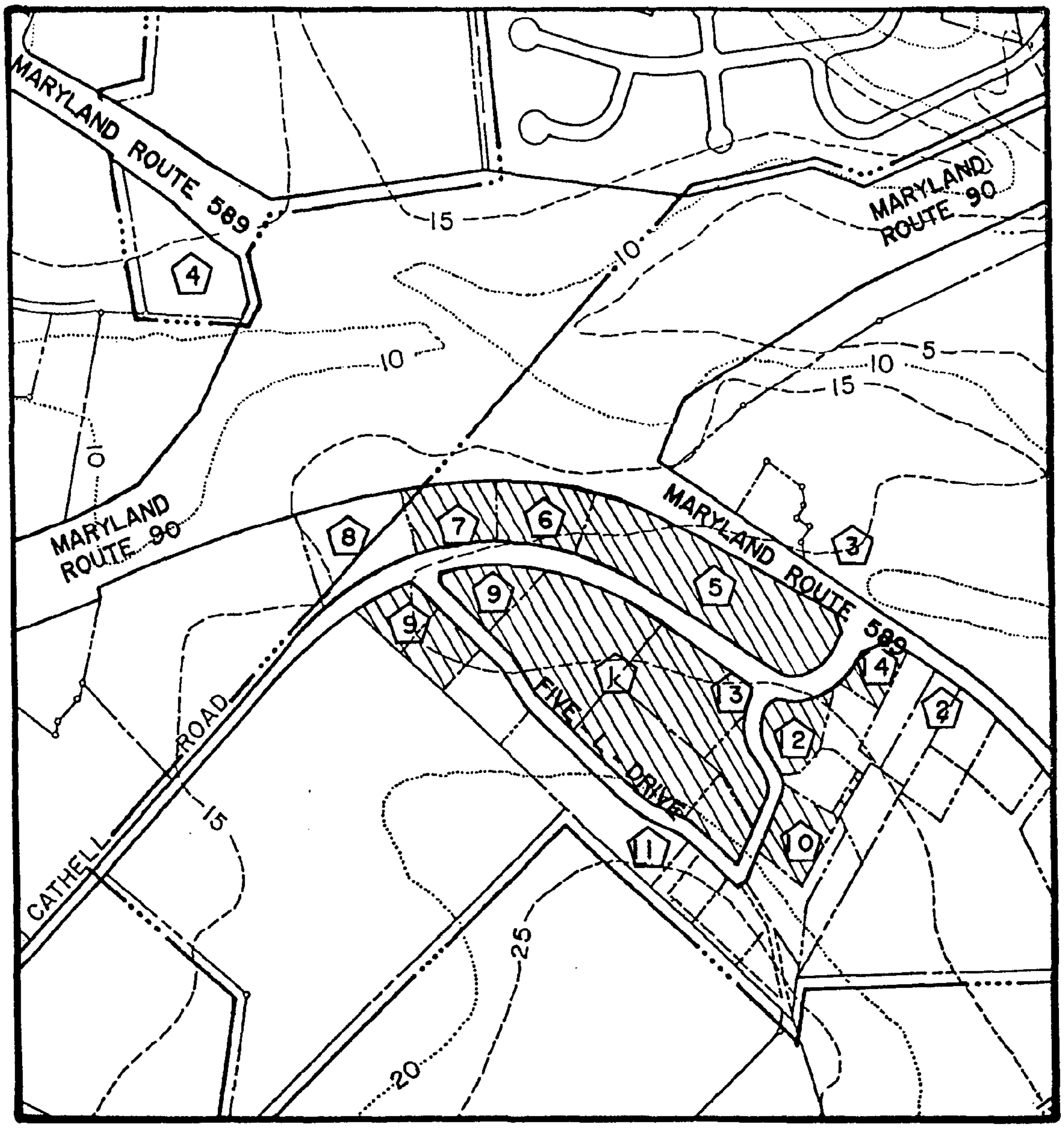
LEGEND

(5) SITE #

(SEE SITE ASSESSMENT DATA SHEETS)

FIGURE 3 - 1

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
DRAINAGE - STORMWATER MANAGEMENT
PROBLEM LOCATION MAP



SCALE 1" = 600'

LEGEND

5 SITE # (SEE SITE ASSESSMENT DATA SHEETS)

PROBLEM AREA

FIGURE 3 - 2

4. STORMWATER MANAGEMENT PROJECTIONS

"Quick TR-55" computer software utilizing the tabular hydrograph method was used to determine the peak discharge (Q) in cfs. The runoff curve number and time of concentration were calculated using the latest TR-55 worksheets (Second Edition). Computer printouts and worksheets may be found in Appendix 2.

Stormwater management calculations were performed for 2 year, 10 year and 25 year, 24-hour rain events for the existing (1988) conditions, assumed future (year 2000) conditions and the ultimate development conditions. Results of these calculations may be found below in Table 4-1 "Peak Stormwater Projections."

TABLE 4-1

PEAK STORMWATER PROJECTIONS

(cfs)

	2 Year Storm	10 Year Storm	25 Year Storm
1988 (existing)	381	755	913
2000 (Future)	695	1331	1596
Ultimate Buildout	927	1644	1936

The Study Area was broken down into four main drainage areas outletting to Manklin Creek as shown in Figure 4-1. The remaining portions of the Study Area drain into other watersheds including Wind Mill Creek and Turville Creek. The total contributory drainage area to Manklin Creek within the Study Area is approximately 800 acres.

As shown in Table 4-1, predicted growth within the Study Area will cause a 82% increase in the two year storm peak discharge by the year 2000, and a possible increase of over 200% if ultimate buildout conditions are reached. As there are existing drainage and stormwater management problems within the Study Area, it is obvious that the anticipated increases in stormwater flow will lead to aggravation of the existing problems. Preliminary calculations of the amount of pond detention storage necessary to control the year 2000 runoff to 1988 levels indicate that a volume of 23.4 acre-feet will be required (see hydrograph overlay number 1, Appendix 2). In addition, calculations indicate that approximately 51.7 acre-feet of storage will be required to manage the ultimate peak discharge to 1988 levels. Given a high value of land in the coastal region, it can be seen that providing proper management could be an expensive proposition.

However, as indicated in Section 2 "Best Management Practices" we do not feel that the County should rely solely on a system of scattered retention ponds. In order to preserve water quality it is necessary to create management designs which address more than the equalization of peak flows.

One of the major runoff characteristic changes caused by development within a watershed is the reduction in stormwater time of concentration. This problem is illustrated by the reduction in total estimated time of concentration from the 1988 figure of 5.5 hours, to 4.15 hours in 2000, to 2.1 hours under ultimate buildout conditions. Typically, most local stormwater management ordinances are very restrictive on peak runoff quantities, but fail to address the character of the runoff. In effect, a reduced time of concentration generally changes runoff characteristics from overland flow to concentrated or point source runoff.

Although the Maryland Department of the Environment, Sediment and Stormwater Division, stresses the use of infiltration measures and other best management practices ahead of alternatives such as dry detention ponds, the relative recentness of this push has not had time to change "standard" ideas in the construction industry; and the high construction costs associated with many infiltration measures add to the disfavorable image of these practices. The future thrust of stormwater management legislation will require management of runoff quality in addition to control of peak outflow quantities.

5.0 REGIONAL RECOMMENDATIONS

The following paragraphs detail actions which may be taken to provide relief to existing drainage problems and to prevent future development from increasing the number and scope of these situations. It apppears that the drainage problems are more a matter of inconvenience than a threat to life or property (with the exception of crawl space flooding under the Groff Building) at this time. As a relatively low, flat area, there will be only a certain amount of drainage capacity possible, after which further increases in stormwater quantities will cause the drainage problems to become more than an inconvenience.

A. The ditches in the existing developed commercial areas of the Study Area consistently showed signs of a lack of maintenence. Most showed signs of sedimentation, weeds, trash, misshapen culverts, and other disfigurements of the flow line. It appears that the site owners are neglecting ditch maintenance, and viewing it as a function of the Worcester County Roads Department. As the geographical size and diversity of the County does not allow the Roads Department to concentrate its maintenance efforts on one small section of the County, it will be necessary to form some type of drainage association or coalition, which will require, at a minimum, the site owners to clean and mow the ditches on a regular basis. It will also be necessary to establish some type of incentive for these owners to take the responsibility seriously, such as a monetary credit for a good maintenance record, or a fine for poor maintenance.

Many of the sites identified in Appendix 1 have recommendations that existing ditches be re-excavated and subsequently stabilized. This should be a first order of business in correcting the problems, and may serve as the focal point for establishing the drainage association. In particular, the regrading of the ditch alongside Site #10, whcih is supposed to handle the southerly portion of the shopping center and associated Five-L Drive properties, should be considered. Sites with specific recommendations for improved drainage include Site #1, 5, 6, 7, 9, 10, 12, 13, and 14. These recommendations may be found in Appendix 1.

B. The major regional drainage features within the Study Area are the large State Highway Administration ditches along the north and south sides of the Maryland Route 90 right-of-way. As identified in the site assessments, these two ditches are wide and deep with large flow capacities which are being reduced by the effects of substantial plant growth within the ditch. These ditches should be maintained to provide as great a flow capacity as possible.

The State Highway Administration's standard stance on the use of its drainage facilities is to limit any contributor to existing flows as of the time the facility was constructed. In view of this, any type of major regional drainage plan should not involve the use of the existing ditches for more than an outlet for stormwater which has previously been managed.

One general type of regional facility which may merit consideration would be to utilize the land adjacent to the State Highway Administration ditches and right-of-way as a low lying "floodable" area which could function in one of two ways: first, the structure could be designed to allow flooding for a period of two days or less, and the land could be used for playing fields or some other type of recreation activity; or, the area could function as a non-tidal wetland with the water standing for a longer period of time with the area serving as a "habitat preserve" for species of plants and wildlife indigenous to local non-tidal wetlands. Either one of these designs would be sized to outlet stormwater to the major ditches at a controlled flowrate, and the extended detention, plus shallow depth of storage, would allow for improvement of stormwater quality.

There are two major considerations which must be addressed to implement a plan of this nature. The first problem involves acquisition of the land, or a right-of-way to the land, adjacent to the ditches. Given the cost of real estate in the Study Area, this may present a significant cost. The second major problem would be designing the structure at a suitable elevation to accept run-off from a large enough area to justify the construction costs, yet still be able to outlet the structure into the existing ditch. However, given the depth of the existing ditch, it is felt that a suitable design could be obtained.

C. Implementation of the best management practices (BMP's) previously detailed in this report should be required on a site-by-site basis throughout the Study Area. This particular strategy will require regulatory "muscle" to put the practices into construction. It remains a regional solution given the necessity of eliminating existing, and preventing future, problems within the Study Area. In particular, the following BMP's should be considered:

1) Use of vegetative filter strips adjacent to paved areas. This is significant in two ways; first, the use of this technology requires sheet flow onto the strips which increases time of concentration; and second, the vegetation provides a means of removing pollutants from the stormwater.

2) All future ditchwork in the area should be designed using wider, flat bottom ditches. A typical ditch would have 4:1 sideslopes (or flatter) with a two (2) foot wide flat bottom (minimum). This practice, while requiring more surface space to be used for drainage, allows for more flow at shallower flow depths. This allows easier maintenance of the ditch, more filtration by vegetation within the ditch, and a greater safety factor if the ditch is overburdened with run-off, or through a lack of maintenance. In general, this type of broad shallow drainage is more in keeping with natural drainage patterns within a coastal area.

3) The use of wet ponds, especially for commercial sites. The typical wet pond in this area should be designed to penetrate permeable soil layers below grade if these are within 10' of grade. The ponds should be designed to depths greater than six feet, should utilize steep sideslopes (1:1 or whatever soil conditions allow) to increase storage per foot of "commercial" area used, and should normally retain the two year storm. Greater storms would discharge through typical pond outlet structures with the 10 year storm outletting at the pre-development 2 year peak outflow. Design of the wet ponds in this manner would allow them to function as infiltration ponds for most storms, but would provide a suitable outlet for more extreme occasions. Use of the bermed infiltration pond has been very successful for disposal of effluent water in the low lying coastal areas of Dorchester County, and should function satisfactorily in other coastal areas if the permeable stratum is reached. An additional benefit of the wet pond is that it allows pollutants to settle out of the stormwater run-off.

Wet ponds also provide the site owner with a source of irrigation water. Instead of using water from a confined aquifer for irrigation, stormwater is an available resource which can be utilized for this purpose if it isn't drained as quickly as possible into the waters of Manklin Creek. A commercial area, such as the Pines Plaza

Shopping Center, could use this water to irrigate the parking lot islands and other landscaped areas. Salisbury State University is currently using a system where parking lot storm drains are connected to stone beds under the parking islands, and the stormwater run-off irrigates the plantings instead of flowing into a tributary of the Wicomico River.

D. There are three non-tidal wetland areas shown on the National Wetlands Inventory (NWI) maps for the area (Salisbury SW 38-22-30, 75-15 and 38-15, 75-15), not including the abandoned gravel pits. These areas are shown in Figure 1-1, 1-2 and 4-1. Two of the areas are adjacent to the State Highway Administration right-of-way for Maryland Route 90 and would make logical choices for areas receiving stormwater management facilities detailed in 5B above (non-tidal wetlands draining to the State Highway Administration ditches).

It is reasonable to expect that non-tidal wetlands will soon be protected from development. The County may be able to begin its protection plan by including these areas into a drainage/stormwater management plan for this Study Area, which would prevent development in these sensitive areas. The major drawback to this aspect of the plan would be identification of the non-tidal wetland areas. The NWI maps have proven to be somewhat difficult to use on a site-by-site basis considering the 1:24,000 scale and their relative inaccuracy. Attempts to use these maps in developing Critical Areas Maps for Dorchester County did not always prove fruitful. Non-tidal wetlands are more accurately located using vegetative and soil indicators during a site investigation.

E. A general suggestion evolving at the beginning of the study highlighted the use of existing gravel pits in the area for accomodation of drainage within the Study Area. After discussion with various local officials, and site investigations, it is not felt that this remains a viable option. Four of the five large borrow pits are located within Ocean Pines, and the management of the Ocean Pines Association is strongly against the introduction of additional drainage and run-off into what they consider to be an overloaded system. The final borrow pit, located to the southwest of the existing commercial center, is located upgrade from existing drainage problems. This can be seen from slide #2-7 found in slide pocket 53. As a result, the use of wet ponds as described in 5C(3) above would be more beneficial.

6.0 REGULATORY GUIDELINES

The development of an "Upper Manklin Creek Watershed" drainage area with stiffer stormwater management requirements is recommended. The requirements would be developed in addition to those already enforced under the Worcester County Natural Resources Article of the Code of Public Laws, Title 2, Subtitle 1, Section 2-101 and following, known as the Stormwater Management Ordinance. Development of these additional criteria should be in accordance with the Maryland Department of Natural Resources, Coastal Resources Division, Policy 4 "Plan and Design Development to Minimize Alterations of the Natural Hydrologic Cycle", excerpted here:

> Strategies for development should focus on duplicating natural hydrologic conditions by using effective site designs and structural approaches that serve a similar function and avoiding structures that block the free movement of water in the system. In general, new development should be designed so that less than fifteen percent of the rainfall on a site is shed as surface runoff. Remaining stormwater should be infiltrated to maintain ground water or should be returned to the atmosphere by evaporation and transpiration. As well, the movement of tides, streams, and rivers should not be impeded by new structures. Development guidelines that can help to achieve these standards include:

1. Incorporate stormwater management practices into design and location criteria for new development.

Infiltrate stormwater runoff from impervious surfaces close to where it falls as rain in order to reduce the need for expensive control and channeling structures and to avoid concentrating impurities to levels that overwhelm the capacity of natural systems. For example,

Break large areas of impervious surface into several smaller areas.

Maintain natural vegetation as open space buffers between adjacent uses and to provide privacy where desirable.

Direct runoff from impervious surfaces across filter strips and through naturally vegetated areas.

Avoid concentrating stormwater into channels, favoring sheet-flow instead.

Use porous surfaces to allow direct infiltration of stormwater.

Where immediate infiltration is impractical, direct stormwater runoff to detention or retention facilities. In this way, excess runoff can be detained long enough to percolate into the ground or can be released at a rate that more nearly approximates natural release rates. This helps to maintain normal, cyclic high and low flow characteristics. For instance,

> Use stormwater retention and detention structures to accomplish both sediment control and toxics removal objectives.
>
> Create stormwater management wetlands, and employ them to slow the movement of stormwater.

Within the framework of this policy, several recommendations for specific regulatory actions are made in the following paragraphs.

A. Protect non-tidal wetlands from development. These areas should be used solely as receiving areas for non-concentrated or shallow concentrated stormwater flows, and these areas should also have positive outflow structures for flows above the storage capacity of the wetlands area. All flows above the natural storage capacity should be released via a positive outlet at the two year design flow. As a minimum requirement, all non-tidal wetland areas should handle, or be enlarged to handle, storage of the post-development five year storm event.

B. All sites slated for development within the Upper Manklin Creek Watershed should be required to utilize best management practices (BMP's) as detailed in

Section 5C and above in the Maryland Department of Natural Resources Policy 4. The order of implementation should be:

1) Total infiltration of the post-development two year storm.

2) Partial infiltration of the post-development ten year storm with the remainder released at the pre-development two year release rate.

3) Use of the wet pond, preferably excavated to a permeable soil stratum, with release of the post-development ten year storm at the pre-development two year storm release rate.

4) Other BMP's as implementable on a site-by-site basis, with particular attention being stressed on vegetative filter strips to improve water quality, and measures to increase the post-development time of concentration such as increased use of sheet flow.

C. Requirements on the particular details of any stormwater management plan within the watershed should include:

1) A maximum size of continuous paving allowed between vegetative filter strips. A recommendation would be to allow no more than 9600 square feet of paving in between twenty feet wide

filter strips. Use of porous pavement where soil conditions permit could be allowed in lieu of this requirement.

2) The use of wider, flatter ditches as mentioned previously. Minimum sideslopes of 4:1 and a bottom width of two feet should be required.

3) Storage of the ten year post-development storm with a two year pre-development release rate for any site using the conventional dry detention pond, or any other method not incorporating the use of BMP.

4) Bond requirements should be increased to include two years of satisfactory operation in addition to construction of the management structures in accordance with the approved plan.

5) All new ditches and drainage facilities should require a maintenance agreement from the site owner to insure the flow capacities of the new facilities (in addition to the maintenance agreement normally required with stormwater management plans).

6) As-built plans of all stormwater management and drainage facilities should be required. These as-built plans should require actual field elevations and locations. It may best serve the County's interests to have the as-builts done by a County

survey crew, with the site owner responsible for the fee. This could be incorporated through additional resources being allocated to the County Roads Department, or the Soil Conservation District. The as-built plans will be the most effective measure possible to insure the proper construction of the proposed drainage and stormwater management facilities.

APPENDIX 1

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Pines Plaza Shopping Center **AREA (ACRES):** 9.7 +/-

SOIL TYPES: WoA (-), En, WdA (-)

LOCATION: Parallel to Cathell Road and Five L Drive
Adjacent to E.S. Adkins

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Five L Drive Roadside Drainage Ditches

SITE DESCRIPTION: Strip shopping center with large parking lot, no curb & gutter in front, landscaped parking islands, loading/unloading area in rear. Access can be obtained from Cathell Road and Five L Drive.

STORMWATER MANAGEMENT MEASURES: Infiltration trenches. Several trenches are located in the parking lot island, others are located in the lawn areas.

DRAINAGE MEASURES: The front parking lot sheet flows toward the parking lot islands and away from the building. This lot also flows toward the drainage ditch along Cathell Road. The rear loading/unloading area drains toward a grass strip between the pavement and the roadside ditch. This grassed area has a long infiltration trench installed in it.

DESCRIPTION OF PROBLEM: The infiltration trenches are not operating adequately. The water level below the grade was found to be anywhere from 12" to 24" below existing grade. There were several low spots around the end of the trenches where water appears to have ponded. Soaker hoses are located in the parking lot islands. These hoses are saturating the soil and carrying sediment into the trenches. Water stains were visible on the pavement where the stormwater has passed the infiltration trenches and flowed to the roadside ditches. The surrounding roadside ditches are in need of cleaning, regrading and stabilization. The ditches along Five L Drive have large amounts of debris and trash in the flowline.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #1

Recommendations:

1. Infiltration trenches should be excavated (test pits) and examined to determine if operational problems are due to clogged media, or failure of the trench to reach a permeable stratum. Further corrective actions on the infiltration trenches would depend upon the findings of the investigations. If the trenches were not excavated to a sufficient depth, the only way to make the system function is to dig up the system, excavate the trenches to a sufficient depth, and reinstall the media. Clogged media at or near the surface of the trenches could be replaced.

   Also, if one does not exist, the Shopping Center owners should be required to sign a Maintenance Agreement which allows the County to yearly inspect and test the facilities at the expense of the owners.

2. Irrigation of vegetation within the parking lot islands has undoubtedly been necessary over the past several summers to maintain healthy plant growth. However, the irrigation should be monitored to prevent over-irrigation and unnecessary run-off into the infiltration trenches.

3. Ditches surrounding the property should be cleaned, regraded and stabilized where the effects of erosion and siltation are present. Ditches which are the responsibility of the County Road Department should be cleaned and mowed and provided general upkeep on a regular basis to prevent the problems present during the site investigations. If the County Road Department does not have the manpower necessary to keep the trash cleaned out of the ditches, a maintenance program placing the burden of responsibility on the site owners should be implemented.

Site #2

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: McDonalds **AREA:** Undetermined

SOIL TYPES: FmB, SaA (-), WdA

LOCATION: South side of Md. Rt. 589 east of the Md. Rt. 90 overpass

CONTRIBUTORY DRAINAGE AREA TO: Md. Rt. 589 drainage ditches (entrances are only contributor.)

SITE DESCRIPTION: McDonalds Fast Food Restaurant with paved parking lot. Access can be gained from Md. Rt. 589.

STORMWATER MANAGEMENT MEASURES: Stormwater management pond and infiltration basin. Appeared to be operating adequately. Pond was large but shallow with a trash "fence" around the outlet. The outlet was a concrete flume with a "V" notch weir to control the discharge. This flume discharges into a small depressed area with approximately 2" - 3" stone lining the bottom.

DRAINAGE MEASURES: Entrances off of Md. Rt. 589 drain to roadside ditches. The remainder of the project area sheet flows to the curb and gutter which slopes towards the rear of the site to "curb cut" outlets which then follow shallow swales to the Stormwater Management Pond.

DESCRIPTION OF PROBLEM: None Present

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Taylor Bank **AREA:** Undetermined

SOIL TYPES: En, WoA, LmB

LOCATION: North side of Md. Rt. 589 at the intersection with Cathell Road

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Md. Rt. 589 roadside drainage ditches

SITE DESCRIPTION: One bank building with drive thru. Paved parking lot and sidewalks near the building. Access can be obtained from Cathell Road.

STORM WATER MANAGEMENT MEASURES: Infiltration trenches (as shown on SCS plans).

DRAINAGE MEASURES: Sheet flow towards roadside drainage ditches

DESCRIPTION OF PROBLEM: None present

Site #4

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Shore Stop/Atlantic National Bank **AREA (ACRES):** 2.9 +/-

SOIL TYPES: Wda, MdB

LOCATION: South side of Md. Rt. 589 west of Md. Rt. 90 overpass

CONTRIBUTORY DRAINAGE AREA TO: Md. Rt. 589 drainage ditch

SITE DESCRIPTION: Two separate buildings with adjoining paved parking lots. One building contains the Atlantic National Bank and the other contains the Shore Stop (a convenience store). Access to both buildings is gained from Md. Rt. 589.

STORMWATER MANAGEMENT MEASURES: Stormwater management pond/sediment basin with riser pipe and outlet to existing drainage ditch.

DRAINAGE MEASURES: Sheet flow across parking lots to storm drain inlets that pipe the runoff to the stormwater management pond. The entrances off of Md. Rt. 589 drain to the roadside ditches.

DESCRIPTION OF PROBLEM: None present. Existing system seems to operate adequately.

Site #5

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Groff Plaza & Groff Real Estate **AREA (ACRES):** 4.4 +/-

SOIL TYPES: WoA, En

LOCATION: North side of Cathell Road at intersection with Md. Rt. 589

CONTRIBUTORY DRAINAGE AREA TO: Md. Rt. 589 and Cathell Road drainage ditches

SITE DESCRIPTION: Two separate buildings with connective gravel parking lots. One building contains several retail businesses and offices. The other building houses Groff Real Estate and Martin Groff Construction. Access can be obtained from Cathell Road.

STORMWATER MANAGEMENT MEASURES: Infiltration basin with overflow to Md. Rt. 589 drainage ditch.

DRAINAGE MEASURES: Roadside ditching along Md. Rt. 589 and Cathell Road. Shallow swales direct stormwater to the infiltration basin and to Md. Rt. 589. Parking lots have little or no slope and sheet flow towards Md. Rt. 589.

DESCRIPTION OF PROBLEM: Drainage and stormwater management systems are overburdened. Stormwater from Pines Plaza Shopping Center ponds at the north side of Cathell Road and follows a shallow, stone lined swale to the infiltration basin. The runoff from Cathell Road and the Pines Plaza Shopping Center has "washed out" portions of the parking lot. The additional runoff has flowed toward the building and collected in the crawl space. The infiltration basin has overflowed and a shallow swale directs the overflow to Md. Rt. 589 drainage ditch.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #5

Recommendations:

1. Stormwater conveyance systems from the Pine Plaza Shopping Center through the site must be improved, or the run-off should be at least partially redirected. From conversations with local officials, it appears that some of this work may have been undertaken since the time of our site investigations. If the burden of the additional of the stormwater from the Pine Plaza Shopping Center is removed from this site, it appears that the existing management facility may be sufficient to handle the site run-off.

Site #6

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Vacant Building (formerly Resort Furnishings) **AREA (ACRES):** 1.5 +/-

SOIL TYPES: WoA

LOCATION: North side of Cathell Road adjacent to Groff Plaza

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Md. Rt. 90 drainage ditches.

SITE DESCRIPTION: Large vacant building located between Cathell Road and Md. Rt. 90 off ramp to Md. Rt. 589. Tar and chip parking lot. Access is gained from Cathell Road through the entrance to Groff Plaza.

STORMWATER MANAGEMENT MEASURES: Infiltration basin. No visible inlet or outlet structures.

DRAINAGE MEASURES: Sheet flow towards infiltration basin and roadside ditches. A small swale starts at the east side of the building and continues to the infiltration basin at Groff Plaza.

DESCRIPTION OF PROBLEM: Infiltration basin not functioning adequately. No emergency spillway, much of the stormwater runoff from the site cannot reach the basin. Ditch along off ramp is very deep with steep sideslopes, and heavy brush and trees.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #6

Recommendations:

1. Drainage of stormwater to the infiltration basin needs to be improved, as the existing sheet flow drainage does not seem to be collecting and carrying the stormwater efficiently. Also, the infiltration basin does not appear to drain adequately. This may be caused by a build-up of sediment in the bottom of the basin, or the basin may not be deep enough. It is recommended that the bottom of the basin be examined and re-excavated if necessary.

2. In addition, it appears that a problem affects the entire area behind Sites 6, 7 and 8 which is the condition of the large, deep ditch, constructed by the State Highway Administration, which serves Route 90. This stormwater conveyance system has developed a heavy brush and small tree cover within the ditch which affects the flow pattern and limits capacity. It is recommended that the State Highway Administration be contacted concerning a possible time schedule for cleaning their ditches in this area.

Site #7

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE:NAME: Caliban **AREA (ACRES):** 1.7 +/-

SOIL TYPES: WoA

LOCATION: North side of Cathell Road adjacent to the Long and Foster Office building.

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Md. Rt. 90 roadside drainage ditches

SITE DESCRIPTION: Office building with gravel parking lot. Large lawn area. Access can be obtained from Cathell Road.

STORMWATER MANAGEMENT MEASURES: None present

DRAINAGE MEASURES: Positive drainage away from building. Sheet flow towards drainage ditches. Ditching along Cathell Road near Md. Rt. 90 and along eastern property line to Md. Rt. 90 ditch.

DESCRIPTION OF PROBLEM: Ditches along property line and near Md. Rt. 90 have heavy brush and small trees throughout. Ditches need to be cleaned, stabilized and maintained.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #7

Recommendations:

1. The ditches along the property lines and in front of this property need to be cleaned, stabilized, and maintained. As noted in the recommendations for Site #1, if the Worcester County Roads Department does not have sufficient manpower to maintain the ditches, the site owners should be required to enter into an agreement for keeping the ditches cleaned out.

Site #8

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Long and Foster **AREA (ACRES):** 1.7 +/-

SOIL TYPES: WoA

LOCATION: North side of Cathell Road across from E.S. Adkins

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Rt. 90 roadside drainage ditch

SITE DESCRIPTION: One building that includes the Long and Foster Realty Office, a mail room, and an Ocean Pines Information Office. Gravel parking lot and well maintained lawn area. Access can be obtained from Cathell Road.

STORMWATER MANAGEMENT MEASURES: None present

DRAINAGE MEASURES: Positive drainage away from building. Sheet flow to adjacent ditches.

DESCRIPTION OF PROBLEM: Ditch along Cathell Road is well maintained. Ditch to the rear of property towards Md. Rt. 90 is very deep with standing water. Sideslopes are steep and heavy brush and small trees are found throughout.

Site #9

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: E.S. Adkins **AREA (ACRES):** 1.1 +/-

SOIL TYPES: WoA

LOCATION: Western intersection of Cathell Road and Five L Drive

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road drainage ditch

SITE DESCRIPTION: Lumber and hardware store with paved parking lot and fenced-in, paved storage area. Access to site can be gained from Cathell Road and Five L Drive.

STORMWATER MANAGEMENT MEASURES: Infiltration trenches with several monitoring wells.

DRAINAGE MEASURES: Sheet flow across parking lot towards infiltration trenches. Roadside ditches along Cathell Road lead to a concrete block holding tank that then releases the stormwater to the ditch further down Cathell road after crossing underneath Five L Drive.

DESCRIPTION OF PROBLEM: Infiltration trenches appear to be working very well. Water level was 3.0' or more below existing grade. The roadside ditches along Cathell Road need to be regraded and stabilized. The existing ditches are in very poor condition towards the rear of the site. The bottoms of the ditches are lined with silt and sediment. A trash rack needs to be installed in the concrete holding tank to prevent trash from being released into the drainage ditch along Cathell Road.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #9

Recommendations:

1. We recommend that the Cathell Road ditches be regraded and stabilized to establish a more defined flowline. An agreement for ditch maintenance should be obtained from the site owners. Also existing on-site ditches in the rear of the site are in poor condition, the bottoms of these ditches need to be re-excavated and stabilized.

2. It is recommended that a trash rack be installed on the concrete stormwater holding tank to prevent trash from being released into the drainage ditch along Cathell Road.

Site #10

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Warehouses **AREA (ACRES):** 1.0 +/-

SOIL TYPES: En

LOCATION: Five L Drive - East end near office building

CONTRIBUTORY DRAINAGE AREA TO: Five L Drive drainage ditch and drainage ditch through woods

SITE DESCRIPTION: Mini-warehouse storage buildings with gravel parking lot/driveways. Six feet tall chain link fence. Access can be obtained from Five L Drive.

STORMWATER MANAGEMENT MEASURES: None present

DRAINAGE MEASURES: Little or no slope on parking lot. Drainage ditch in rear is half in the woods, it appears to have little or no slope.

DESCRIPTION OF PROBLEM: Ditches need cleared so that trees and brush do not restrict the flow. The ditch in the rear does not appear to have a positive outlet.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #10

Recommendations:

1. The drainage problems on this site do not affect the warehouses structurally, but are symptomatic of the drainage problems in this area of the commercial center. Ditches surrounding the property need to be cleaned and stabilized.

2. The ditch in the rear of this site is supposedly the main outlet for the southerly portion of the commercial center. We recommend that since the ditch does not appear to have a positive outlet, that it be deepened to such an extent, if possible, that it becomes an infiltration basin which is shaped basically as a ditch.

Site #11

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Ocean Glass and Mirror **AREA (ACRES):**

SOIL TYPES: En, SaC_2

LOCATION: Five L Drive, behind Pines Plaza Shopping Center

CONTRIBUTORY DRAINAGE AREA TO: Five L Drive drainage ditches

SITE DESCRIPTION: Large metal building with gravel parking lot. Cleared lot, wooded in rear.

STORMWATER MANAGEMENT MEASURES: None present

DRAINAGE MEASURES: Well graded site with positive drainage away from building. Roadside drainage ditches along Five L Drive are very well constructed and maintained. No drainage problems visible.

DESCRIPTION OF PROBLEM: None present

Site #12

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Office Building **AREA (ACRES):** 1.2 +/-

SOIL TYPES: WdA

LOCATION: East side of intersection of Cathell road and Five L Drive

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Five L Drive roadside ditches

SITE DESCRIPTION: One building containing several offices: State Farm Insurance, Flower Shop, Atlantic Resorts Reception Center, Century 21 and a vacant office. Tar and chip parking lot on all sides. Access is gained from Cathell road and Five L Drive.

STORMWATER MANAGEMENT MEASURES: None present

DRAINAGE MEASURES: The parking lot sheet flows towards roadside ditches. The ditch along Cathell Road high points on this property and flows in both directions away from the site. The ditch along Five L Drive high points approximately 100' from the intersection, flowing towards the Mini-warehouses to the south and the storm drain culvert at the intersection of Cathell Road and Five L Drive to the north.

DESCRIPTION OF PROBLEM: The roadside ditches should be cleaned and maintained on a regular basis. The storm drain pipe under the northeastern entrance is half of a pipe diameter below the ditch bottom. The ditch along Cathell Road has no bank adjacent to the parking lot. A more definite flow line for stormwater should be provided.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #12

Recommendations:

1. Again, as with Site #10, the problems on this site are symptomatic of that portion of the commercial development area. The site owners need to establish a flow line along the front of the property toward the culvert pipes located at either side of the property.

Site #13

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: Pines Plaza Car Wash **AREA (ACRES):** 0.9 +/-

SOIL TYPES: Wda, En

LOCATION: West side of intersection of Cathell Road and Five L Drive

CONTRIBUTORY DRAINAGE AREA TO: Cathell Road and Five L Drive drainage ditches.

SITE DESCRIPTION: Five bay car wash. Paved parking lot, no curb and gutter. Self contained washing bays. Access to the site is gained from the Pines Plaza Shopping Center parking lot.

STORMWATER MANAGEMENT MEASURES: Infiltration/retention basins. Two basins found in this vicinity. Neither structure utilized inlet or outlet structures. Emergency overflow appears to be the nearby drainage ditches.

DRAINAGE MEASURES: The washing bays are self contained and drain to inlets in each bay. The parking lot and surrounding lawn areas sheet flow towards the infiltration/retention areas.

DESCRIPTION OF PROBLEM: The infiltration/retention basins do not appear to be operating adequately. The water level is high and does not appear as though it drops. These areas have visibly overflowed into the nearby drainage ditches. The area to the southeast has not been properly stabilized and the sides have caved in. There is standing water between this area and the parking lot. The basin to the northwest had a scum layer on top of the water. Stormwater sheet flowing from Pines Plaza Shopping Center has eroded the soil at the edge of the pavement adjacent to the pond. Ditches along both roads need to be cleaned, regraded and stabilized.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #13

Recommendations:

1. Infiltration basins are not operating adequately and need to be re-excavated to remove silt and/or to reach a more permeable layer. The southeast side of the property needs to be stabilized. In addition, the area between the parking lot and infiltration basin needs to be graded to prevent water from standing in this area. Also, ditches along the road front need to be cleaned, regraded and stabilized, and a maintenance agreement provided.

Site #14

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE NAME: 7-11 **AREA (ACRES):** 0.7 +/-

SOIL TYPES: SaA, FmB

LOCATION: East side of intersection of Md. Rt. 589 and Cathell Road

CONTRIBUTORY DRAINAGE AREA TO: Md. Rt. 589 - roadside drainage ditches

SITE DESCRIPTION: One commercial building (convenience store), gasoline pumping island with overhead canopy. Paved parking lot with curb and gutter and a sidewalk near the building. Entrance to the site can be obtained from Md. Rt. 589 and Cathell Road.

STORMWATER MANAGEMENT MEASURES: None present

DRAINAGE MEASURES: Parking lot and surrounding lawn areas sheet flow towards the roadside ditches. The northwestern corner of the parking lot has a curb opening that outlets into the ditch along Md. Rt. 589. The gasoline pumping area is self contained with a storm drain inlet that outlets to the ditch along Cathell Road.

DESCRIPTION OF PROBLEM: The curb opening in the northwest corner needs some sort of erosion control measure to prevent the sides of the existing ditch from eroding. The inlet in the gasoline pumping island either does not have a grease interceptor or an existing structure of this type is not operating adequately to prevent oil and/or grease from reaching the roadside ditch.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY
SITE ASSESSMENT DATA

SITE #14

Recommendations:

1. The curb opening in the northwest corner of the property needs stone riprap and gravel outlet protection to control the erosion now occurring on the side of the ditch.

2. The inlet in the gasoline pumping island needs to have a grease interceptor installed, or if there is an existing grease interceptor, it is not being maintained properly. The owners of the property should be required to enter into an agreement, in either case, to assure that oil and grease does not continue to reach the roadside ditch. This type of problem is reflective of the stormwater quality aspect of drainage problems, and needs to be addressed as such.

WORCESTER COUNTY COMMISSIONERS
UPPER MANKLIN CREEK DRAINAGE STUDY

SLIDE DESCRIPTIONS

Set 1, Slides taken August, 1988
AMA 88116
Worcester County Commissioners
Upper Manklin Creek Drainage Study

Slides taken on-site at the Maryland Route 90 and Maryland Route 589 intersection.

Slide #1-1 - intersection of Cathell Road and Route 589 on the corner of 7-11. (Found in slide pocket 56)

Slide #1-2 - outlet pipe which discharges into the ditch along Cathell Road. This outlet pipe appears to come from the inlet that is located in 7-11's gas pumping islands. (Found in slide pocket 33)

Slide #1-3 - end of a culvert pipe which crosses under an entrance to the office building. (Found in slide pocket 31)

Slide #1-4 - the opposite end of the culvert pipe that goes to the office building. (Found in slide pocket 32)

Slide #1-5 - Five L Drive from Cathell Road looking towards the mini-warehouse buildings with the office building on the left. (Found in slide pocket 30)

Slide #1-6 - Groff Plaza from Five L Drive, car wash on the left, office building on the right. (Found in slide pocket 26)

Slide #1-7 - parking lot at Pines Plaza car wash, looking towards the infiltration pond near shopping center entrance. (Found in slide pocket 21)

Slide #1-8 - infiltration basin at the Pines Plaza car wash near shopping center entrance. (Found in slide pocket 23)

Slide #1-9 - ditch along Cathell Road near the car wash in front of Pines Plaza Shopping Center. (Found in slide pocket 19)

Slide #1-10 - front of the parking lot at Pines Plaza Shopping Center from the car wash. (Found in slide pocket 22)

Slide #1-11 - Sediment Basin near the Pines Plaza car wash. (Beside pump station.) (Found in slide pocket 25)

Slide #12 - opposite side of the sediment basin near Pines Plaza car wash. (Found in slide pocket 24)

Slide #1-13 - Pines Plaza Shopping Center parking lot sloping towards car wash. (Found in slide pocket 20)

Slide #1-14 - one of the infiltration trenches in the parking lot islands at Pines Plaza Shopping Center. (Found in slide pocket 9)

Slide #1-15 - low area adjacent to one of the infiltration trenches in the Pines Plaza Shopping Center, also shows the soaker hose nearby for irrigation. (Found in slide pocket 10)

Slide #1-16 - water level in one of the monitoring wells at one of the infiltration trenches in Pines Plaza Shopping Center. (Found in slide pocket 11)

Slide #1-18 - Pines Plaza Shopping Center sign. (Found in slide pocket 6)

Slide #1-19 - end of the culvert pipe under the entrance to Pines Plaza Shopping Center. Toward E.S. Adkins along Cathell Road. (Found in Slide Pocket 15)

Slide #1-20 - looking from the culvert in slide #19. (Found in slide pocket 14)

Slide #1-21 - overview looking across the parking lot at Pines Plaza Shopping Center. (Found in slide pocket 8)

Slide #1-22 - infiltration trench in the lot beside Pines Plaza Shopping Center. (Found in slide pocket 13)

Slide #1-23 - large drainage ditch along Five L Drive behind Pines Plaza Shopping Center in between the shopping center and E.S. Adkins. (Found in slide pocket 18)

Slide #1-24 - opposite end of the drainage ditch on Five L Drive behind Pines Plaza Shopping Center. (Found in slide pocket 17)

Set 2, Slides taken August, 1988

Slide #2-1 - parking lot behind Pines Plaza Shopping Center looking towards Ocean Glass & Mirror. (Found in slide pocket 13)

Slide #2-2 - drainage ditch along Five L Drive behind Pines Plaza Shopping Center in towards E.S. Adkins. (Found in slide pocket 16)

Slide #2-3 - drainage ditch behind the vacant lot on Five L Drive. (Found in slide pocket 29)

Slide #2-4 - pipe which crosses under the road which supposedly drains the drainage ditch along Five L Drive into the drainage ditch in the woods. (Found in slide pocket 27)

Slide #2-5 - corner of Five L Drive, notice to aforementioned outlet pipe. This corner is lower then the outlet pipe and has standing water in it. (Found in slide pocket 28)

Slide #2-6 - large pond off of Five L Drive appears to be a large abandoned gravel pit. (Found in slide pocket 54)

Slide #2-7 - gravel road leading towards the abandoned gravel pit. (Found in slide pocket 53)

Slide #2-8 - concrete holding structure located on E.S. Adkins property at the corner of Five L Drive and Cathell Road. (Found in slide pocket 45)

Slide #2-9 - drainage ditch along Cathell Road leading towards the concrete holding structure. (Found in slide pocket 44)

Slide #2-10 - end of a curb return along Cathell Road near E.S. Adkins. (Found in slide pocket 46)

Slide #2-11 - infiltration trench at E.S. Adkins. (Found in slide pocket 42)

Slide #2-12 - drainage ditch along Cathell Road looking towards Groff Plaza in front of E.S. Adkins. (Found in slide pocket 43)

Slide #2-13 - drainage ditch near E.S. Adkins along Cathell Road. (Found in slide pocket 47)

Slide #2-14 - opposite end of the drainage ditch near E.S. Adkins on Cathell Road. (Found in slide pocket 48)

Slide #2-15 - beginning where Cathell Road separates from the drainage ditch along where Old Cathell Road use to be. (Found in slide pocket 39)

Slide #2-16 - off-ramp of Md. Route 90 along the drainage ditch from Old Cathell Road. (Found in slide pocket 40)

Slide #2-17 - infiltration pond located on a lot with a vacant building which use to be Resort Furnishings. (Found in slide pocket 37)

Slide #2-18 - Groff Plaza Building. (Found in slide pocket 34)

Slide #2-19 - infiltration basin at Groff Plaza. (Found in slide pocket 36)

Slide #2-20 - ditch from Cathell Road on Groff Plaza property leading towards the infiltration basin. (Found in slide pocket 35)

Slide #2-21 - Md. Route 589 from the intersection of Cathell Road. (Found in slide pocket 55)

Slide #2-22 - stormwater management pond/infiltration basin at the Atlantic National Bank/Shore Stop on Md. Route 589. (Found in slide pocket 49)

Slide #2-23 - rip rap line outlet to the pond at Atlantic National Bank/Shore Stop. (Found in slide pocket 50)

Set 3, Slides taken August, 1988

Slide #3-1 - Md. Route 90 off-ramp along the drainage ditch along Route 90 towards Long and Foster building. (Found in slide pocket 41)

Slide #3-2 - Md. Route 90 off-ramp again looking towards the Long and Foster Building. (Found in slide pocket 38)

Slide #3-3 - Cathell Road extended to the Ocean Pines pool on the left, a small swale runs into the abandoned gravel pit. (Found in slide pocket 69)

Slide #3-4 - near the pool at Ocean Pines towards Taylor Bank and Md. Route 589. (Found in slide pocket 68)

Slide #3-5 - storm drain culvert under Md. Route 589 near the off-ramp to Route 90. (Found in slide pocket 60)

Slide #3-6 - Md. Route 90 and its intersection with Md. Route 589. (Found in slide pocket 62)

Slide #3-7 - outlet point where the ditch along Md. Route 90 discharges into the woods. (Found in slide pocket 67)

Slide #3-8 - culvert under Md. Route 90 which begins along Md Route 589. (Found in slide pocket 66)

Slide #3-9 - Md. Route 90 and Md. Route 589, outlet point in the foreground. (Found in slide pocket 64)

Slide #3-10 - Md. Route 90 (East) outlet point in the foreground. (Found in slide pocket 65)

Slide #3-11 - high point on Md. Route 90 at which the drainage along this road goes toward the aforementioned outlet point and in an opposite direction, thus ending the drainage area along this road. (Found in slide pocket 63)

Slide #3-12 - culvert under Md. Route 589 on the opposite side of the road from Atlantic National Bank. (Found in slide pocket 59)

Slide #3-13 - Md. Route 589 looking towards the intersection with Md. Route 90, taken near the Shore Stop. (Found in slide pocket 58)

Slide #3-14 - looking the opposite direction along Md. Route 589 taken near Atlantic National Bank looking towards one of the gates at Ocean Pines. (Found in slide pocket 57)

Slide #3-15 - drainage ditch that comes from Md. Route 90 and meanders up near Atlantic National Bank crosses under Md. Route 589 to go towards Route 90 again and outlet into the woods. (Found in slide pocket 61)

Slide #3-16 - stormwater management pond at McDonalds on Md. Route 589. (Found in slide pocket 51)

Slide #3-17 - concrete flume outlet with a V notch weir on the stormwater management pond at McDonalds. (Found in slide pocket 52)

Slide #3-18 - Md. Route 589 looking towards the Pine Plaza Shopping Center entrance. (Found in slide pocket 1)

Slide #3-19 - Md. Route 589 the south entrance of Ocean Pines. (Found in slide pocket 2)

Slide #3-20 - small swale on a sample Nanticoke home lot which crosses underneath Md. Route 589 and toward one of the abandoned borrow pits near Ocean Pines south entrance flows. (Found in slide pocket 70)

Slide #3-21 - one of the borrow pits near Ocean Pines south entrance. (Found in slide pocket 4)

Slide #3-22 - abandoned borrow pit in the Ocean Pines south entrance. (Found in slide pocket 5)

Slide #3-23 - Md. Route 589 opposite McDonalds looking towards the south entrance to Ocean Pines. (Found in slide pocket 3)

Slide #3-24 - Pine Plaza Shopping Center. (Found in slide pocket 7)

(slides.wor)

APPENDIX 2

Appendix 2 is grouped by sections into existing, future, and ultimate site conditions. Each section contains runoff curve number calculations and time of concentration calculations by drainage area, with the end of each section containing tabular hydrograph output for the two, ten and twenty-five year storm events. The tabular hydrograph output consists of sets of six sheets for each storm event. The fourth section of Appendix 2 contains four examples of hydrograph overlay calculations which reflect detention storage required to reduce to various future storm flow events to the two-year 1988 levels.

APPENDIX 2, SECTION 1

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed   Drainage Area # 1

Existing Conditions (1988)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi^2 ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92			4	368
C	" "	94			4	376
D	" "	95				
—	IMPERVIOUS AREA Roadways & Rooftops	98			15	1470
—	Ponds	98			15	1470
A	WOODS	30				
B	"	55			26	1430
C	"	70			31	2170
D	"	77			41	3157
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75			25	1875
C	" "	82			29	2378
D	" "	85			45	3825
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			10	750
C	"	83			24	1992
D	"	87			31	2697
					300	23958

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{23958}{300} = 79.9$; $\boxed{80}$

		Storm #1	Storm #2	Storm #3
Frequency	yr	2	10	25
Rainfall, P (24-hour)	in	3.6	5.6	6.4
Runoff, Q	in			

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed Drainage Area # 1

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	A		
1.	Surface description (table 3-1)		Cult. Field		
2.	Manning's roughness coeff., n (table 3-1) ..		0.17		
3.	Flow length, L (total L ≤ 300 ft)	ft	300		
4.	Two-yr 24-hr rainfall, P_2	in	3.6		
5.	Land slope, s	ft/ft	.005		
6.	$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	.71	+	= .71

Shallow concentrated flow

		Segment ID	B		
7.	Surface description (paved or unpaved)		Unpaved		
8.	Flow length, L	ft	2000'		
9.	Watercourse slope, s	ft/ft	.001		
10.	Average velocity, V (figure 3-1)	ft/s	1.1		
11.	$T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.51	+	= .51

Channel flow

		Segment ID	C		
12.	Cross sectional flow area, a	ft^2			
13.	Wetted perimeter, p_w	ft			
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15.	Channel slope, s	ft/ft	.001		
16.	Manning's roughness coeff., n		.10		
17.	$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	1.0		
18.	Flow length, L	ft	3600		
19.	$T_t = \frac{L}{3600\,V}$ Compute T_t	hr	1.0	+	= 1.0
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			2.22

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY   By K.B.E.   Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD   Checked ____   Date ____

Circle one: Present Developed   Drainage Area #1 & 3 # 4

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID			
1. Surface description (table 3-1)					
2. Manning's roughness coeff., n (table 3-1)					
3. Flow length, L (total L ≤ 300 ft)	ft				
4. Two-yr 24-hr rainfall, P_2	in				
5. Land slope, s	ft/ft				
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr		+	=	

Shallow concentrated flow

		Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=	

Channel flow

		Segment ID			
		A			
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft	.001			
16. Manning's roughness coeff., n		.10			
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	1.0			
18. Flow length, L	ft	2250			
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.63	+	=	.63

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr **.63**

Project: UPPER MANKLIN CREEK DRAINAGE STUDY By: K.B.E. Date: 11/88

Location: MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD Checked: ____ Date: ____

Circle one: Present Developed *Drainage Area # 2*

Existing Conditions (1988)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN [1/] Fig. 2-3	CN [1/] Fig. 2-4	Area ☒ acres ☐ mi^2 ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92			2	184
C	" "	94			10	940
D	" "	95			15	1425
—	IMPERVIOUS AREA Roadways & Rooftops	98			20	1960
—	Ponds	98			6	588
A	WOODS	30				
B	"	55			3	165
C	"	70			39	2730
D	"	77			55	4235
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82			12	984
D	" "	85			8	680
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75				
C	"	83				
D	"	87				
					170	13891

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{13891}{170} = 81.7$; Use CN = $\boxed{82}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4
Runoff, Q .... in			

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed Drainage Area #2

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	A			
1.	Surface description (table 3-1)		Woods			
2.	Manning's roughness coeff., n (table 3-1) ..		0.4			
3.	Flow length, L (total L $\leq$ 300 ft)	ft	300			
4.	Two-yr 24-hr rainfall, P_2	in	3.6			
5.	Land slope, s	ft/ft	.002			
6.	$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	2.0	+		= 2.0

Shallow concentrated flow

		Segment ID	B			
7.	Surface description (paved or unpaved)		Unpaved			
8.	Flow length, L	ft	350			
9.	Watercourse slope, s	ft/ft	.002			
10.	Average velocity, V (figure 3-1)	ft/s	1.1			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.09	+		= .09

Channel flow

		Segment ID	C			
12.	Cross sectional flow area, a	ft^2				
13.	Wetted perimeter, p_w	ft				
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15.	Channel slope, s	ft/ft	.001			
16.	Manning's roughness coeff., n		.036			
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	1.44			
18.	Flow length, L	ft	925			
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.18	+		= .18
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr				2.27

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area #2

Circle one: T_c T_t through subarea 3 & 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Unit			
Segment ID				
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L ≤ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow	Unit			
Segment ID				
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=

Channel flow	Unit			
Segment ID		A	B	
12. Cross sectional flow area, a	ft^2	~~.001~~		
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001	.001	
16. Manning's roughness coeff., n		.10	.03	
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	1.0	2.7	
18. Flow length, L	ft	2250	3100	
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.63	+ .32	= 0.95

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.95

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area # 3

Existing Conditions (1988)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN Fig. 2-3	CN Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89			3	267
B	" "	92			12	1104
C	" "	94			25	2350
D	" "	95			20	1900
—	IMPERVIOUS AREA Roadways & Rooftops	98			30	2940
—	Ponds	98			20	1960
A	WOODS	30			15	225
B	"	55			7	385
C	"	70			8	560
D	"	77			5	385
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82			5	410
D	" "	85			5	425
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			5	375
C	"	83				
D	"	87			15	1305
B	Open Space	65			3	195
C		77			7	539
D		82			5	410
					190	15375

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{15375}{190} = 80.9$; Use CN = $\boxed{81}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4
Runoff, Q .... in			

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed Drainage Area #3

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Segment ID		A		
1. Surface description (table 3-1)			Pave		
2. Manning's roughness coeff., n (table 3-1) ..			.011		
3. Flow length, L (total L ≤ 300 ft)		ft	360		
4. Two-yr 24-hr rainfall, P_2		in	3.6		
5. Land slope, s		ft/ft	.005		
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$	Compute T_t	hr	.08	+	= .08
Shallow concentrated flow	Segment ID				
7. Surface description (paved or unpaved)					
8. Flow length, L		ft			
9. Watercourse slope, s		ft/ft			
10. Average velocity, V (figure 3-1)		ft/s			
11. $T_t = \frac{L}{3600\ V}$	Compute T_t	hr		+	=
Channel flow	Segment ID		B		
12. Cross sectional flow area, a		ft^2			
13. Wetted perimeter, p_w		ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$	Compute r	ft			
15. Channel slope, s		ft/ft	.001		
16. Manning's roughness coeff., n			.03		
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$	Compute V	ft/s	2.7		
18. Flow length, L		ft	4200		
19. $T_t = \frac{L}{3600\ V}$	Compute T_t	hr	.43	+	= .43
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)		hr			.51

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area #1 & 3

Circle one: T_c T_t through subarea # 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID			
1. Surface description (table 3-1)					
2. Manning's roughness coeff., n (table 3-1)					
3. Flow length, L (total L ≤ 300 ft)	ft				
4. Two-yr 24-hr rainfall, P_2	in				
5. Land slope, s	ft/ft				
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$ Compute T_t	hr		+	=	

Shallow concentrated flow

		Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=	

Channel flow

		Segment ID A			
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft	.001			
16. Manning's roughness coeff., n		.10			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	1.0			
18. Flow length, L	ft	2250			
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.63	+	=	.63

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr .63

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed Drainage Area # 4

Existing Conditions (1988)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	Fig. 2-3	Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92				
C	" "	94				
D	" "	95				
—	IMPERVIOUS AREA Roadways & Rooftops	98			15	1470
—	Ponds	98				
A	WOODS	30			3	90
B	"	55			5	275
C	"	70			12	840
D	"	77			20	1540
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64			5	305
B	" "	75			22	1650
C	" "	82			30	2490
D	" "	85			28	2436
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75				
C	"	83				
D	"	87				
					140	11096

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{11096}{140} = 79.2$; $\boxed{79}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4
Runoff, Q .... in			

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date ______

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ______ Date ______

Circle one: Present Developed — Drainage Area # 4

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Units	Segment A	Segment 2	Total
Segment ID		A		
1. Surface description (table 3-1)		Cult. field		
2. Manning's roughness coeff., n (table 3-1)		0.17		
3. Flow length, L (total L ≤ 300 ft)	ft	300'		
4. Two-yr 24-hr rainfall, P_2	in	3.6		
5. Land slope, s	ft/ft	.03		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$ Compute T_t	hr	.35	+	= .35

Shallow concentrated flow

	Units	Segment B	Segment 2	Total
Segment ID		B		
7. Surface description (paved or unpaved)		Unpaved		
8. Flow length, L	ft	600'		
9. Watercourse slope, s	ft/ft	.005		
10. Average velocity, V (figure 3-1)	ft/s	1.1		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.15	+	= .15

Channel flow

	Units	Segment C	Segment 2	Total
Segment ID		C		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001		
16. Manning's roughness coeff., n		.10		
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	1.0		
18. Flow length, L	ft	1500		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.42	+	= .42
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			.92

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 08:52:18
Watershed File --> C:UMCE11 .WSD Hydrograph File --> C:UMCE11 .HYD

Hydrograph for the two year storm given existing conditions in August 1988

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
Drainage Area 1	300.00	80.0	2.00	0.75	3.60	1.72	.14	.10
Drainage Area 2	170.00	82.0	2.00	1.00	3.60	1.87	.12	.10
Drainage Area 3	190.00	81.0	0.50	0.75	3.60	1.79	.13	.10
Drainage Area 4	140.00	79.0	1.00	0.00	3.60	1.64	.15	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 381 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	2.00	0.63	2.00	0.75	No	--
Drainage Area 2	2.00	0.95	2.00	1.00	No	--
Drainage Area 3	0.51	0.63	0.50	0.75	No	--
Drainage Area 4	0.92	0.00	1.00	0.00	No	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 08:52:18

Watershed File --> C:UMCE11 .WSD Hydrograph File --> C:UMCE11 .HYD

Hydrograph for the two year storm given existing conditions in August 1988

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	163	14.0
Drainage Area 2	100	14.3
Drainage Area 3	199	13.2
Drainage Area 4	128	12.8
Composite Watershed	381	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 08:52:18
Watershed File --> C:UMCE11 .WSD Hydrograph File --> C:UMCE11 .HYD

Hydrograph for the two year storm given existing conditions in
August 1988

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	3	5	6	7	8	9	10	10	12
Drainage Area 2	1	2	3	3	4	4	4	5	5
Drainage Area 3	5	6	7	10	11	13	14	16	20
Drainage Area 4	4	5	7	10	13	17	26	40	60
Total (cfs)	13	18	23	30	36	43	54	71	97

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	15	18	22	28	47	73	104	132	154
Drainage Area 2	6	7	8	9	14	23	37	55	73
Drainage Area 3	26	39	63	97	170	199	174	130	90
Drainage Area 4	83	104	118	128	112	86	63	48	37
Total (cfs)	130	168	211	262	343	381	378	365	354

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 08:52:18
Watershed File --> C:UMCE11 .WSD Hydrograph File --> C:UMCE11 .HYD

Hydrograph for the two year storm given existing conditions in
August 1988

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	163	156	135	101	70	51	39	31	26
Drainage Area 2	88	100	96	77	54	38	28	21	17
Drainage Area 3	62	40	30	23	19	16	15	13	12
Drainage Area 4	30	23	18	14	12	10	9	8	8
Total (cfs)	343	319	279	215	155	115	91	73	63

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	22	18	15	11	5
Drainage Area 2	15	11	9	7	4
Drainage Area 3	11	10	9	6	1
Drainage Area 4	7	6	5	4	0
Total (cfs)	55	45	38	28	10

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 08:52:18
Watershed File --> C:UMCE11 .WSD Hydrograph File --> C:UMCE11 .HYD

Hydrograph for the two year storm given existing conditions in August 1988

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	13	14.8	247
11.1	15	14.9	231
11.2	16	15.0	215
11.3	18	15.1	203
11.4	20	15.2	191
11.5	21	15.3	179
11.6	23	15.4	167
11.7	25	15.5	155
11.8	28	15.6	147
11.9	30	15.7	139
12.0	36	15.8	131
12.1	43	15.9	123
12.2	54	16.0	115
12.3	71	16.1	110
12.4	97	16.2	105
12.5	130	16.3	101
12.6	168	16.4	96
12.7	211	16.5	91
12.8	262	16.6	87
12.9	303	16.7	84
13.0	343	16.8	80
13.1	362	16.9	77
13.2	381	17.0	73
13.3	380	17.1	71
13.4	378	17.2	69
13.5	372	17.3	67
13.6	365	17.4	65
13.7	360	17.5	63
13.8	354	17.6	61
13.9	349	17.7	60
14.0	343	17.8	58
14.1	335	17.9	57
14.2	327	18.0	55
14.3	319	18.1	54
14.4	306	18.2	53
14.5	292	18.3	52
14.6	279	18.4	51
[illegible]	[illegible]	[illegible]	[illegible]

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 08:52:18
Watershed File --> C:UMCE11 .WSD Hydrograph File --> C:UMCE11 .HYD

Hydrograph for the two year storm given existing conditions in August 1988

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	49	22.4	26
18.7	48	22.5	26
18.8	47	22.6	25
18.9	46	22.7	25
19.0	45	22.8	24
19.1	44	22.9	24
19.2	44	23.0	24
19.3	43	23.1	23
19.4	42	23.2	23
19.5	42	23.3	22
19.6	41	23.4	22
19.7	40	23.5	21
19.8	39	23.6	21
19.9	39	23.7	20
20.0	38	23.8	20
20.1	38	23.9	19
20.2	37	24.0	19
20.3	37	24.1	19
20.4	36	24.2	18
20.5	36	24.3	18
20.6	35	24.4	17
20.7	35	24.5	17
20.8	34	24.6	16
20.9	34	24.7	16
21.0	33	24.8	15
21.1	33	24.9	15
21.2	32	25.0	15
21.3	32	25.1	14
21.4	31	25.2	14
21.5	31	25.3	13
21.6	30	25.4	13
21.7	30	25.5	12
21.8	29	25.6	12
21.9	29	25.7	11
22.0	28	25.8	11
22.1	28	25.9	10
22.2	27		
22.3	27		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:02:20
Watershed File --> C:UMCE12 .WSD Hydrograph File --> C:UMCE12 .HYD

Hydrograph for the ten year storm given existing conditions in August 1988

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used
Drainage Area 1	300.00	80.0	2.00	0.75	5.60	3.42	.09 .10
Drainage Area 2	170.00	82.0	2.00	1.00	5.60	3.62	.08 .10
Drainage Area 3	190.00	81.0	0.50	0.75	5.60	3.52	.08 .10
Drainage Area 4	140.00	79.0	1.00	0.00	5.60	3.32	.09 .10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 755 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	2.00	0.63	2.00	0.75	No	Computed Ia/p < .1
Drainage Area 2	2.00	0.95	2.00	1.00	No	Computed Ia/p < .1
Drainage Area 3	0.51	0.63	0.50	0.75	No	Computed Ia/p < .1
Drainage Area 4	0.92	0.00	1.00	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:02:20
Watershed File --> C:UMCE12 .WSD Hydrograph File --> C:UMCE12 .HYD

Hydrograph for the ten year storm given existing conditions in
August 1988

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	324	14.0
Drainage Area 2	193	14.3
Drainage Area 3	391	13.2
Drainage Area 4	259	12.8
Composite Watershed	755	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:02:20
Watershed File --> C:UMCE12 .WSD Hydrograph File --> C:UMCE12 .HYD

Hydrograph for the ten year storm given existing conditions in
August 1988

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	6	10	11	14	16	18	19	21	24
Drainage Area 2	3	4	6	7	8	8	9	10	11
Drainage Area 3	9	11	15	20	22	25	28	32	39
Drainage Area 4	8	11	15	21	25	34	52	81	122
Total (cfs)	26	36	47	62	71	85	108	144	196

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	29	35	43	56	93	146	207	263	306
Drainage Area 2	12	13	15	17	27	44	71	106	141
Drainage Area 3	51	77	123	190	333	391	343	255	177
Drainage Area 4	168	210	239	259	227	174	127	97	75
Total (cfs)	260	335	420	522	680	755	748	721	699

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:02:20
Watershed File --> C:UMCE12 .WSD Hydrograph File --> C:UMCE12 .HYD

Hydrograph for the ten year storm given existing conditions in August 1988

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	324	311	268	200	139	101	77	61	51
Drainage Area 2	171	193	186	150	104	73	54	41	34
Drainage Area 3	122	79	59	45	37	32	29	26	23
Drainage Area 4	60	46	36	29	24	21	19	17	15
Total (cfs)	677	629	549	424	304	227	179	145	123

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	43	35	29	22	10
Drainage Area 2	29	22	18	13	8
Drainage Area 3	22	19	17	13	1
Drainage Area 4	15	12	11	9	0
Total (cfs)	109	88	75	57	19

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:02:20
Watershed File --> C:UMCE12 .WSD Hydrograph File --> C:UMCE12 .HYD

Hydrograph for the ten year storm given existing conditions in
August 1988

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	26	14.8	486
11.1	29	14.9	455
11.2	33	15.0	424
11.3	36	15.1	400
11.4	40	15.2	376
11.5	43	15.3	352
11.6	47	15.4	328
11.7	52	15.5	304
11.8	57	15.6	289
11.9	62	15.7	273
12.0	71	15.8	258
12.1	85	15.9	242
12.2	108	16.0	227
12.3	144	16.1	217
12.4	196	16.2	208
12.5	260	16.3	198
12.6	335	16.4	189
12.7	420	16.5	179
12.8	522	16.6	172
12.9	601	16.7	165
13.0	680	16.8	159
13.1	718	16.9	152
13.2	755	17.0	145
13.3	752	17.1	141
13.4	748	17.2	136
13.5	735	17.3	132
13.6	721	17.4	127
13.7	710	17.5	123
13.8	699	17.6	120
13.9	688	17.7	117
14.0	677	17.8	115
14.1	661	17.9	112
14.2	645	18.0	109
14.3	629	18.1	107
14.4	602	18.2	105
14.5	576	18.3	103
14.6	549	18.4	101
14.7	518	18.5	99

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:02:20
Watershed File --> C:UMCE12 .WSD Hydrograph File --> C:UMCE12 .HYD

Hydrograph for the ten year storm given existing conditions in August 1988

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	96	22.4	53
18.7	94	22.5	52
18.8	92	22.6	51
18.9	90	22.7	50
19.0	88	22.8	49
19.1	87	22.9	48
19.2	85	23.0	48
19.3	84	23.1	47
19.4	83	23.2	46
19.5	82	23.3	45
19.6	80	23.4	44
19.7	79	23.5	43
19.8	78	23.6	42
19.9	76	23.7	41
20.0	75	23.8	40
20.1	74	23.9	39
20.2	73	24.0	38
20.3	72	24.1	37
20.4	71	24.2	36
20.5	71	24.3	35
20.6	70	24.4	34
20.7	69	24.5	33
20.8	68	24.6	32
20.9	67	24.7	31
21.0	66	24.8	30
21.1	65	24.9	29
21.2	64	25.0	29
21.3	63	25.1	28
21.4	62	25.2	27
21.5	62	25.3	26
21.6	61	25.4	25
21.7	60	25.5	24
21.8	59	25.6	23
21.9	58	25.7	22
22.0	57	25.8	21
22.1	56	25.9	20
22.2	55		
22.3	54		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:03:34
Watershed File --> C:UMCE13 .WSD Hydrograph File --> C:UMCE13 .HYD

Hydrograph for the twenty-five year storm given existing conditions for August 1988.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used
Drainage Area 1	300.00	80.0	2.00	0.75	6.40	4.14	.08 .10
Drainage Area 2	170.00	82.0	2.00	1.00	6.40	4.36	.07 .10
Drainage Area 3	190.00	81.0	0.50	0.75	6.40	4.25	.07 .10
Drainage Area 4	140.00	79.0	1.00	0.00	6.40	4.04	.08 .10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 913 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	2.00	0.63	2.00	0.75	No	Computed Ia/p < .1
Drainage Area 2	2.00	0.95	2.00	1.00	No	Computed Ia/p < .1
Drainage Area 3	0.51	0.63	0.50	0.75	No	Computed Ia/p < .1
Drainage Area 4	0.92	0.00	1.00	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:03:34
Watershed File --> C:UMCE13 .WSD Hydrograph File --> C:UMCE13 .HYD

Hydrograph for the twenty-five year storm given existing conditions for August 1988.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	392	14.0
Drainage Area 2	233	14.3
Drainage Area 3	472	13.2
Drainage Area 4	315	12.8
Composite Watershed	913	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:03:34
Watershed File --> C:UMCE13 .WSD Hydrograph File --> C:UMCE13 .HYD

Hydrograph for the twenty-five year storm given existing conditions for August 1988.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	8	12	14	17	19	21	23	25	29
Drainage Area 2	3	5	7	8	9	9	10	12	13
Drainage Area 3	11	14	18	24	26	30	34	39	47
Drainage Area 4	10	13	18	26	31	42	64	99	148
Total (cfs)	32	44	57	75	85	102	131	175	237

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	35	43	52	68	113	177	250	318	371
Drainage Area 2	14	16	19	21	32	53	86	127	170
Drainage Area 3	62	93	149	230	402	472	414	308	213
Drainage Area 4	204	255	291	315	277	211	155	118	91
Total (cfs)	315	407	511	634	824	913	905	871	845

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:03:34
Watershed File --> C:UMCE13 .WSD Hydrograph File --> C:UMCE13 .HYD

Hydrograph for the twenty-five year storm given existing conditions for August 1988.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	392	376	324	243	169	122	93	74	62
Drainage Area 2	206	233	224	181	125	88	65	50	41
Drainage Area 3	148	96	71	54	44	39	35	32	28
Drainage Area 4	73	56	44	35	29	26	23	20	19
Total (cfs)	819	761	663	513	367	275	216	176	150

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	52	43	35	27	12
Drainage Area 2	35	27	22	16	9
Drainage Area 3	26	23	20	15	1
Drainage Area 4	18	15	13	11	0
Total (cfs)	131	108	90	69	22

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:03:34
Watershed File --> C:UMCE13 .WSD Hydrograph File --> C:UMCE13 .HYD

Hydrograph for the twenty-five year storm given existing conditions for August 1988.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	32	14.8	588
11.1	36	14.9	550
11.2	40	15.0	513
11.3	44	15.1	484
11.4	48	15.2	455
11.5	53	15.3	425
11.6	57	15.4	396
11.7	63	15.5	367
11.8	69	15.6	349
11.9	75	15.7	330
12.0	85	15.8	312
12.1	102	15.9	293
12.2	131	16.0	275
12.3	175	16.1	263
12.4	237	16.2	251
12.5	315	16.3	240
12.6	407	16.4	228
12.7	511	16.5	216
12.8	634	16.6	208
12.9	729	16.7	200
13.0	824	16.8	192
13.1	869	16.9	184
13.2	913	17.0	176
13.3	909	17.1	171
13.4	905	17.2	166
13.5	888	17.3	160
13.6	871	17.4	155
13.7	858	17.5	150
13.8	845	17.6	146
13.9	832	17.7	142
14.0	819	17.8	139
14.1	800	17.9	135
14.2	780	18.0	131
14.3	761	18.1	129
14.4	728	18.2	126
14.5	696	18.3	124
14.6	663	18.4	122
14.7	625	18.5	120

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:03:34
Watershed File --> C:UMCE13 .WSD Hydrograph File --> C:UMCE13 .HYD

Hydrograph for the twenty-five year storm given existing conditions for August 1988.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	117	22.4	64
18.7	115	22.5	63
18.8	113	22.6	62
18.9	110	22.7	61
19.0	108	22.8	60
19.1	106	22.9	58
19.2	104	23.0	57
19.3	103	23.1	56
19.4	101	23.2	55
19.5	99	23.3	54
19.6	97	23.4	53
19.7	95	23.5	51
19.8	94	23.6	50
19.9	92	23.7	49
20.0	90	23.8	48
20.1	89	23.9	47
20.2	88	24.0	46
20.3	87	24.1	44
20.4	86	24.2	43
20.5	85	24.3	42
20.6	84	24.4	41
20.7	83	24.5	40
20.8	82	24.6	38
20.9	81	24.7	37
21.0	80	24.8	36
21.1	78	24.9	35
21.2	77	25.0	34
21.3	76	25.1	33
21.4	75	25.2	31
21.5	74	25.3	30
21.6	73	25.4	29
21.7	72	25.5	28
21.8	71	25.6	27
21.9	70	25.7	26
22.0	69	25.8	24
22.1	68	25.9	23
22.2	67		
22.3	65		

APPENDIX 2, SECTION 2

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY MD Checked ____ Date ____

Circle one: Present (Developed) Drainage Area # 1

Future (Year 2000)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi^2 ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92			5	460
C	" "	94			5	470
D	" "	95			2	190
—	IMPERVIOUS AREA Roadways & Rooftops	98			18	1764
—	Ponds	98			15	1470
A	WOODS	30				
B	"	55			22	1210
C	"	70			26	1820
D	"	77			34	2618
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75			21	1575
C	" "	82			24	1968
D	" "	85			37	3145
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			12	900
C	"	83			29	2407
D	"	87			38	3306
B	2 Acre Lots	65			3	195
C	"	77			4	308
D	"	82			5	410
					300	24216

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{24216}{300} = 80.7$; Use CN = 81

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area # 1

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID	A			
1. Surface description (table 3-1)			High Density Res.			
2. Manning's roughness coeff., n (table 3-1) ..			.011			
3. Flow length, L (total L ≤ 300 ft)	ft		300'			
4. Two-yr 24-hr rainfall, P_2	in		3.6			
5. Land slope, s	ft/ft		.005			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$	hr	Compute T_t	.08	+		= .08

Shallow concentrated flow		Segment ID				
7. Surface description (paved or unpaved)						
8. Flow length, L	ft					
9. Watercourse slope, s	ft/ft					
10. Average velocity, V (figure 3-1)	ft/s					
11. $T_t = \frac{L}{3600\ V}$	hr	Compute T_t		+		=

Channel flow		Segment ID	B			
12. Cross sectional flow area, a	ft^2					
13. Wetted perimeter, p_w	ft					
14. Hydraulic radius, $r = \frac{a}{p_w}$	ft	Compute r				
15. Channel slope, s	ft/ft		.001			
16. Manning's roughness coeff., n			.10			
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$	ft/s	Compute V	1.0			
18. Flow length, L	ft		1800			
19. $T_t = \frac{L}{3600\ V}$	hr	Compute T_t	0.5	+		= 0.5
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr					0.58

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present **Developed** Drainage Area # 1

Circle one: T_c **T_t** through subarea # 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Unit	Segment ID		
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L ≤ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow	Unit	Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=

Channel flow	Unit	Segment ID A		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001		
16. Manning's roughness coeff., n		.10		
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	1.0		
18. Flow length, L	ft	2250		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.63	+	= .63

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr .63

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present (Developed) Drainage Area # 2

Future (Year 2000)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1] Table 2-2	CN [1] Fig. 2-3	CN [1] Fig. 2-4	Area ☒acres ☐mi^2 ☐%	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92			3	276
C	" "	94			12	1128
D	" "	95			18	1710
—	IMPERVIOUS AREA Roadways & Rooftops	98			24	2352
—	Ponds	98			6	588
A	WOODS	30				
B	"	55			2	110
C	"	70			32	2240
D	"	77			45	3465
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82			10	820
D	" "	85			7	595
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75				
C	"	83				
D	"	87				
B	2 Acre Lots	65			3	195
C	"	77			4	308
D	"	82			4	328
					170	14115

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{14115}{170} = 83.0$; Use CN = $\boxed{83}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present (Developed) Drainage Area #2

Circle one: (T_c) T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	A			
1.	Surface description (table 3-1)		Woods			
2.	Manning's roughness coeff., n (table 3-1) ..		0.40			
3.	Flow length, L (total L $\le$ 300 ft)	ft	300			
4.	Two-yr 24-hr rainfall, P_2	in	3.6			
5.	Land slope, s	ft/ft	.005			
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	1.41	+		= 1.41

Shallow concentrated flow

		Segment ID	B			
7.	Surface description (paved or unpaved)		Unpaved			
8.	Flow length, L	ft	200			
9.	Watercourse slope, s	ft/ft	.005			
10.	Average velocity, V (figure 3-1)	ft/s	1.1			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.05	+		= .05

Channel flow

		Segment ID	C			
12.	Cross sectional flow area, a	ft^2				
13.	Wetted perimeter, P_w	ft				
14.	Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft				
15.	Channel slope, s	ft/ft	.001			
16.	Manning's roughness coeff., n		.036			
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	1.44			
18.	Flow length, L	ft	1350			
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.26	+		= .26
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr				1.72

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area #2

Circle one: T_c T_t through subarea 3 & 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Unit			
Segment ID				
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L ≤ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow	Unit			
Segment ID				
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=

Channel flow	Unit			
Segment ID		A	B	
12. Cross sectional flow area, a	ft^2	?		
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001	.001	
16. Manning's roughness coeff., n		.10	.03	
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	1.0	2.7	
18. Flow length, L	ft	2250	3100	
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.63	+ .32	= .95
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.95

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present (Developed)

Drainage Area # 3

Future (Year 2000)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89			4	356
B	" "	92			15	1380
C	" "	94			30	2820
D	" "	95			24	2280
—	IMPERVIOUS AREA Roadways & Rooftops	98			36	3528
—	Ponds	98			20	1960
A	WOODS	30			12	360
B	"	55			6	330
C	"	70			7	490
D	"	77			4	303
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82			4	328
D	" "	85			4	340
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			6	450
C	"	83				
D	"	87			18	1566
B	2 Acre Lots	65				
C	"	77				
D	"	82				
					190	16491

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{16491}{190} = 86.8$; Use CN = $\boxed{87}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area # 3

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID	A		
1. Surface description (table 3-1)			Impervious		
2. Manning's roughness coeff., n (table 3-1) ..			.011		
3. Flow length, L (total L $\leq$ 300 ft)	ft		300'		
4. Two-yr 24-hr rainfall, P_2	in		3.6		
5. Land slope, s	ft/ft		.005		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$	hr	Compute T_t	.08	+	= .08

Shallow concentrated flow		Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\,V}$	hr	Compute T_t		+	=

Channel flow		Segment ID	B		
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft		.001		
16. Manning's roughness coeff., n			.03		
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$	ft/s	Compute V	2.7		
18. Flow length, L	ft		3900'		
19. $T_t = \frac{L}{3600\,V}$	hr	Compute T_t	.40	+	= .40

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr **.48**

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project: UPPER MANKLIN CREEK DRAINAGE STUDY By: K.B.E. Date: 11/88

Location: MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked: ____ Date: ____

Circle one: Present Developed Drainage Area # 3

Circle one: T_c T_t through subarea # 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Unit	Segment ID		
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L $\leq$ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow

	Unit	Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

	Unit	Segment ID A		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001		
16. Manning's roughness coeff., n		.10		
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	1.0		
18. Flow length, L	ft	2250		
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.63	+	= 0.63

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.63

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present (Developed) Drainage Area # 4

Future (Year 2000)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	Fig. 2-3	Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89			2	178
B	" "	92			2	184
C	" "	94			2	188
D	" "	95			2	190
—	IMPERVIOUS AREA Roadways & Rooftops	98			18	1764
—	Ponds	98				
A	WOODS	30			2	60
B	"	55			4	220
C	"	70			10	700
D	"	77			17	1309
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64			4	256
B	" "	75			18	1350
C	" "	82			25	2050
D	" "	85			23	1955
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			4	300
C	"	83			3	249
D	"	87			4	348
B	2 Acre Lots	65				
C	"	77				
D	"	82				
					140	11301

$$CN \text{ (weighted)} = \frac{\text{total product}}{\text{total area}} = \frac{11301}{140} = 80.7; \quad \boxed{81}$$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed Drainage Area # 4

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Unit	Segment 1	Segment 2	Total
Segment ID		A		
1. Surface description (table 3-1)		Fields		
2. Manning's roughness coeff., n (table 3-1) ..		0.17		
3. Flow length, L (total L ≤ 300 ft)	ft	300		
4. Two-yr 24-hr rainfall, P_2	in	3.6		
5. Land slope, s	ft/ft	.005		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$ Compute T_t	hr	.71	+	= .71

Shallow concentrated flow

	Unit	Segment 1	Segment 2	Total
Segment ID		B		
7. Surface description (paved or unpaved)		Unpaved		
8. Flow length, L	ft	600		
9. Watercourse slope, s	ft/ft	.001		
10. Average velocity, V (figure 3-1)	ft/s	1.1		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.15	+	= .15

Channel flow

	Unit	Segment 1	Segment 2	Total
Segment ID		C		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001		
16. Manning's roughness coeff., n		.10		
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	1.0		
18. Flow length, L	ft	1560		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.43	+	= .43
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			1.29

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:12:27
Watershed File --> C:UMCF11 .WSD Hydrograph File --> C:UMCF11 .HYD

Hydrograph for assumed future conditions for the year 2000.
Two year storm.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
Drainage Area 1	300.00	81.0	0.50	0.75	3.60	1.79	.13	.10
Drainage Area 2	170.00	83.0	2.00	0.75	3.60	1.94	.11	.10
Drainage Area 3	190.00	87.0	0.40	0.75	3.60	2.27	.08	.10
Drainage Area 4	140.00	81.0	1.25	0.00	3.60	1.79	.13	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 695 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	0.58	0.63	0.50	0.75	No	--
Drainage Area 2	1.72	0.95	2.00	0.75	No	--
Drainage Area 3	0.48	0.63	0.40	0.75	No	Computed Ia/p < .1
Drainage Area 4	1.29	0.00	1.25	0.00	No	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:12:27
Watershed File --> C:UMCF11 .WSD Hydrograph File --> C:UMCF11 .HYD

Hydrograph for assumed future conditions for the year 2000.
Two year storm.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	314	13.2
Drainage Area 2	104	14.0
Drainage Area 3	265	13.0
Drainage Area 4	122	13.0
Composite Watershed	695	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:12:27
Watershed File --> C:UMCF11 .WSD Hydrograph File --> C:UMCF11 .HYD

Hydrograph for assumed future conditions for the year 2000.
Two year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	8	9	12	16	18	20	23	26	31
Drainage Area 2	2	3	4	5	5	6	6	7	8
Drainage Area 3	7	9	11	16	18	20	24	30	44
Drainage Area 4	4	5	7	10	11	15	21	32	46
Total (cfs)	21	26	34	47	52	61	74	95	129

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	41	62	99	153	268	314	275	205	142
Drainage Area 2	9	11	14	18	30	47	66	85	98
Drainage Area 3	71	115	169	220	265	230	165	111	75
Drainage Area 4	64	83	100	111	122	104	83	64	51
Total (cfs)	185	271	382	502	685	695	589	465	366

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:12:27
Watershed File --> C:UMCF11 .WSD Hydrograph File --> C:UMCF11 .HYD

Hydrograph for assumed future conditions for the year 2000.
Two year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	98	64	47	36	29	26	23	21	18
Drainage Area 2	104	100	86	64	45	32	25	20	16
Drainage Area 3	55	40	32	26	22	20	18	15	14
Drainage Area 4	41	31	24	18	14	12	11	9	9
Total (cfs)	298	235	189	144	110	90	77	65	57

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	18	15	13	10	1
Drainage Area 2	14	11	9	7	3
Drainage Area 3	13	12	10	8	0
Drainage Area 4	8	7	6	5	0
Total (cfs)	53	45	38	30	4

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:12:27
Watershed File --> C:UMCF11 .WSD Hydrograph File --> C:UMCF11 .HYD

Hydrograph for assumed future conditions for the year 2000.
Two year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	21	14.8	166
11.1	23	14.9	155
11.2	24	15.0	144
11.3	26	15.1	137
11.4	29	15.2	130
11.5	31	15.3	124
11.6	34	15.4	117
11.7	38	15.5	110
11.8	43	15.6	106
11.9	47	15.7	102
12.0	52	15.8	98
12.1	61	15.9	94
12.2	74	16.0	90
12.3	95	16.1	87
12.4	129	16.2	85
12.5	185	16.3	82
12.6	271	16.4	80
12.7	382	16.5	77
12.8	502	16.6	75
12.9	594	16.7	72
13.0	685	16.8	70
13.1	690	16.9	67
13.2	695	17.0	65
13.3	642	17.1	63
13.4	589	17.2	62
13.5	527	17.3	60
13.6	465	17.4	59
13.7	415	17.5	57
13.8	366	17.6	56
13.9	332	17.7	55
14.0	298	17.8	55
14.1	277	17.9	54
14.2	256	18.0	53
14.3	235	18.1	52
14.4	220	18.2	51
14.5	204	18.3	51
14.6	189	18.4	50
14.7	178	18.5	49

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:12:27
Watershed File --> C:UMCF11 .WSD Hydrograph File --> C:UMCF11 .HYD

Hydrograph for assumed future conditions for the year 2000.
Two year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	48	22.4	27
18.7	47	22.5	27
18.8	47	22.6	26
18.9	46	22.7	25
19.0	45	22.8	25
19.1	44	22.9	24
19.2	44	23.0	24
19.3	43	23.1	23
19.4	42	23.2	22
19.5	42	23.3	22
19.6	41	23.4	21
19.7	40	23.5	20
19.8	39	23.6	20
19.9	39	23.7	19
20.0	38	23.8	18
20.1	38	23.9	18
20.2	37	24.0	17
20.3	37	24.1	16
20.4	36	24.2	16
20.5	36	24.3	15
20.6	36	24.4	14
20.7	35	24.5	14
20.8	35	24.6	13
20.9	34	24.7	12
21.0	34	24.8	12
21.1	34	24.9	11
21.2	33	25.0	11
21.3	33	25.1	10
21.4	32	25.2	9
21.5	32	25.3	9
21.6	32	25.4	8
21.7	31	25.5	7
21.8	31	25.6	7
21.9	30	25.7	6
22.0	30	25.8	5
22.1	29	25.9	5
22.2	29		
22.3	28		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:15:02
Watershed File --> C:UMCF12 .WSD Hydrograph File --> C:UMCF12 .HYD

Hydrograph for assumed future conditions for the year 2000.
Ten year storm.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
Drainage Area 1	300.00	81.0	0.50	0.75	5.60	3.52	.08	.10
Drainage Area 2	170.00	83.0	2.00	0.75	5.60	3.72	.07	.10
Drainage Area 3	190.00	87.0	0.40	0.75	5.60	4.14	.05	.10
Drainage Area 4	140.00	81.0	1.25	0.00	5.60	3.52	.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 1331 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	0.58	0.63	0.50	0.75	No	Computed Ia/p < .1
Drainage Area 2	1.72	0.95	2.00	0.75	No	Computed Ia/p < .1
Drainage Area 3	0.48	0.63	0.40	0.75	No	Computed Ia/p < .1
Drainage Area 4	1.29	0.00	1.25	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:15:02
Watershed File --> C:UMCF12 .WSD Hydrograph File --> C:UMCF12 .HYD

Hydrograph for assumed future conditions for the year 2000.
Ten year storm.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	617	13.2
Drainage Area 2	200	14.0
Drainage Area 3	483	13.0
Drainage Area 4	239	13.0
Composite Watershed	1331	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:15:02
Watershed File --> C:UMCF12 .WSD Hydrograph File --> C:UMCF12 .HYD

Hydrograph for assumed future conditions for the year 2000.
Ten year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	15	18	23	31	35	40	45	51	61
Drainage Area 2	4	6	7	9	10	11	12	13	15
Drainage Area 3	12	16	21	29	32	37	43	55	80
Drainage Area 4	8	10	14	19	22	29	42	62	91
Total (cfs)	39	50	65	88	99	117	142	181	247

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	81	122	195	300	526	617	541	403	279
Drainage Area 2	18	22	27	35	57	90	127	162	189
Drainage Area 3	130	209	308	401	483	419	301	202	138
Drainage Area 4	126	164	197	219	239	205	163	126	99
Total (cfs)	355	517	727	955	1305	1331	1132	893	705

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:15:02
Watershed File --> C:UMCF12 .WSD Hydrograph File --> C:UMCF12 .HYD

Hydrograph for assumed future conditions for the year 2000.
Ten year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	193	125	92	71	58	51	46	41	36
Drainage Area 2	200	192	165	124	86	62	47	38	32
Drainage Area 3	100	73	59	48	41	37	32	28	26
Drainage Area 4	80	60	47	36	28	24	21	18	17
Total (cfs)	573	450	363	279	213	174	146	125	111

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	35	30	26	20	2
Drainage Area 2	27	22	18	14	6
Drainage Area 3	25	22	18	15	0
Drainage Area 4	15	14	12	9	1
Total (cfs)	102	88	74	58	9

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:15:02
Watershed File --> C:UMCF12 .WSD Hydrograph File --> C:UMCF12 .HYD

Hydrograph for assumed future conditions for the year 2000.
Ten year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	39	14.8	321
11.1	43	14.9	300
11.2	46	15.0	279
11.3	50	15.1	266
11.4	55	15.2	253
11.5	60	15.3	239
11.6	65	15.4	226
11.7	73	15.5	213
11.8	80	15.6	205
11.9	88	15.7	197
12.0	99	15.8	190
12.1	117	15.9	182
12.2	142	16.0	174
12.3	181	16.1	168
12.4	247	16.2	163
12.5	355	16.3	157
12.6	517	16.4	152
12.7	727	16.5	146
12.8	955	16.6	142
12.9	1130	16.7	138
13.0	1305	16.8	133
13.1	1318	16.9	129
13.2	1331	17.0	125
13.3	1231	17.1	122
13.4	1132	17.2	119
13.5	1013	17.3	117
13.6	893	17.4	114
13.7	799	17.5	111
13.8	705	17.6	109
13.9	639	17.7	107
14.0	573	17.8	106
14.1	532	17.9	104
14.2	491	18.0	102
14.3	450	18.1	101
14.4	421	18.2	99
14.5	392	18.3	98
14.6	363	18.4	96
14.7	342	18.5	95

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:15:02
Watershed File --> C:UMCF12 .WSD Hydrograph File --> C:UMCF12 .HYD

Hydrograph for assumed future conditions for the year 2000.
Ten year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	94	22.4	53
18.7	92	22.5	52
18.8	91	22.6	51
18.9	89	22.7	49
19.0	88	22.8	48
19.1	87	22.9	47
19.2	85	23.0	46
19.3	84	23.1	45
19.4	82	23.2	43
19.5	81	23.3	42
19.6	80	23.4	41
19.7	78	23.5	40
19.8	77	23.6	38
19.9	75	23.7	37
20.0	74	23.8	36
20.1	73	23.9	35
20.2	72	24.0	34
20.3	72	24.1	32
20.4	71	24.2	31
20.5	70	24.3	30
20.6	69	24.4	29
20.7	68	24.5	27
20.8	68	24.6	26
20.9	67	24.7	25
21.0	66	24.8	24
21.1	65	24.9	22
21.2	64	25.0	21
21.3	64	25.1	20
21.4	63	25.2	19
21.5	62	25.3	18
21.6	61	25.4	16
21.7	60	25.5	15
21.8	60	25.6	14
21.9	59	25.7	13
22.0	58	25.8	11
22.1	57	25.9	10
22.2	56		
22.3	54		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:20:53
Watershed File --> C:UMCF13 .WSD Hydrograph File --> C:UMCF13 .HYD

Hydrograph for assumed future conditions for the year 2000.
Twenty-five year storm.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used
Drainage Area 1	300.00	81.0	0.50	0.75	6.40	4.25	.07 .10
Drainage Area 2	170.00	83.0	2.00	0.75	6.40	4.46	.06 .10
Drainage Area 3	190.00	87.0	0.40	0.75	6.40	4.90	.05 .10
Drainage Area 4	140.00	81.0	1.25	0.00	6.40	4.25	.07 .10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 1596 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	0.58	0.63	0.50	0.75	No	Computed Ia/p < .1
Drainage Area 2	1.72	0.95	2.00	0.75	No	Computed Ia/p < .1
Drainage Area 3	0.48	0.63	0.40	0.75	No	Computed Ia/p < .1
Drainage Area 4	1.29	0.00	1.25	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:20:53
Watershed File --> C:UMCF13 .WSD Hydrograph File --> C:UMCF13 .HYD

Hydrograph for assumed future conditions for the year 2000.
Twenty-five year storm.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	745	13.2
Drainage Area 2	239	14.0
Drainage Area 3	572	13.0
Drainage Area 4	289	13.0
Composite Watershed	1596	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:20:53
Watershed File --> C:UMCF13 .WSD Hydrograph File --> C:UMCF13 .HYD

Hydrograph for assumed future conditions for the year 2000.
Twenty-five year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	18	22	28	38	42	48	54	62	74
Drainage Area 2	5	7	8	11	12	13	14	15	18
Drainage Area 3	15	19	25	35	38	44	51	65	95
Drainage Area 4	9	12	17	23	27	35	50	75	110
Total (cfs)	47	60	78	107	119	140	169	217	297

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	98	147	235	363	636	745	653	486	337
Drainage Area 2	21	26	32	41	69	108	153	194	226
Drainage Area 3	154	247	365	474	572	496	356	239	163
Drainage Area 4	152	198	238	264	289	247	197	152	120
Total (cfs)	425	618	870	1142	1566	1596	1359	1071	846

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:20:53
Watershed File --> C:UMCF13 .WSD Hydrograph File --> C:UMCF13 .HYD

Hydrograph for assumed future conditions for the year 2000.
Twenty-five year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	233	151	112	86	70	62	56	50	44
Drainage Area 2	239	230	198	148	103	75	57	45	38
Drainage Area 3	118	86	70	57	48	44	38	33	31
Drainage Area 4	97	73	57	44	34	29	25	22	20
Total (cfs)	687	540	437	335	255	210	176	150	133

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	42	36	32	24	2
Drainage Area 2	32	26	21	17	7
Drainage Area 3	29	26	22	17	0
Drainage Area 4	19	17	15	11	1
Total (cfs)	122	105	90	69	10

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:20:53
Watershed File --> C:UMCF13 .WSD Hydrograph File --> C:UMCF13 .HYD

Hydrograph for assumed future conditions for the year 2000.
Twenty-five year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	47	14.8	386
11.1	51	14.9	360
11.2	56	15.0	335
11.3	60	15.1	319
11.4	66	15.2	303
11.5	72	15.3	287
11.6	78	15.4	271
11.7	88	15.5	255
11.8	97	15.6	246
11.9	107	15.7	237
12.0	119	15.8	228
12.1	140	15.9	219
12.2	169	16.0	210
12.3	217	16.1	203
12.4	297	16.2	196
12.5	425	16.3	190
12.6	618	16.4	183
12.7	870	16.5	176
12.8	1142	16.6	171
12.9	1354	16.7	166
13.0	1566	16.8	160
13.1	1581	16.9	155
13.2	1596	17.0	150
13.3	1477	17.1	147
13.4	1359	17.2	143
13.5	1215	17.3	140
13.6	1071	17.4	136
13.7	958	17.5	133
13.8	846	17.6	131
13.9	766	17.7	129
14.0	687	17.8	126
14.1	638	17.9	124
14.2	589	18.0	122
14.3	540	18.1	120
14.4	506	18.2	119
14.5	471	18.3	117
14.6	437	18.4	115
14.7	411	18.5	114

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:20:53
Watershed File --> C:UMCF13 .WSD Hydrograph File --> C:UMCF13 .HYD

Hydrograph for assumed future conditions for the year 2000.
Twenty-five year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	112	22.4	63
18.7	110	22.5	62
18.8	108	22.6	60
18.9	107	22.7	59
19.0	105	22.8	57
19.1	104	22.9	56
19.2	102	23.0	54
19.3	101	23.1	53
19.4	99	23.2	51
19.5	98	23.3	50
19.6	96	23.4	48
19.7	95	23.5	47
19.8	93	23.6	45
19.9	92	23.7	44
20.0	90	23.8	42
20.1	89	23.9	41
20.2	88	24.0	40
20.3	87	24.1	38
20.4	86	24.2	37
20.5	85	24.3	35
20.6	84	24.4	34
20.7	83	24.5	32
20.8	82	24.6	31
20.9	81	24.7	29
21.0	80	24.8	28
21.1	78	24.9	26
21.2	77	25.0	25
21.3	76	25.1	23
21.4	75	25.2	22
21.5	74	25.3	20
21.6	73	25.4	19
21.7	72	25.5	17
21.8	71	25.6	16
21.9	70	25.7	14
22.0	69	25.8	13
22.1	68	25.9	11
22.2	66		
22.3	65		

APPENDIX 2, SECTION 3

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present Developed

Drainage Area # 1
Ultimate Development

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi^2 ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92			15	1380
C	" "	94			30	2820
D	" "	95			30	2850
—	IMPERVIOUS AREA Roadways & Rooftops	98			31	3038
—	Ponds	98			40	3920
A	WOODS	30				
B	"	55				
C	"	70				
D	"	77				
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82				
D	" "	85				
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			12	900
C	"	83			29	2407
D	"	87			38	3306
B	2 Acre Lots	65			20	1300
C	"	77			25	1925
D	"	82			30	2460
					300	26306

N (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{26306}{300} = 87.7$; $\boxed{88}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed Drainage Area # 1

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID	A			
1. Surface description (table 3-1)			High Density Res.			
2. Manning's roughness coeff., n (table 3-1) ..			0.011			
3. Flow length, L (total L $\leq$ 300 ft)	ft		300			
4. Two-yr 24-hr rainfall, P_2	in		3.6			
5. Land slope, s	ft/ft		.005			
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$	hr	Compute T_t	.08	+		= .08

Shallow concentrated flow		Segment ID	B			
7. Surface description (paved or unpaved)			Unpaved			
8. Flow length, L	ft		1200'			
9. Watercourse slope, s	ft/ft		.005			
10. Average velocity, V (figure 3-1)	ft/s		1.1			
11. $T_t = \frac{L}{3600\ V}$	hr	Compute T_t	.30	+		= .30

Channel flow		Segment ID	C			
12. Cross sectional flow area, a	ft^2					
13. Wetted perimeter, p_w	ft					
14. Hydraulic radius, $r = \frac{a}{p_w}$	ft	Compute r				
15. Channel slope, s	ft/ft		.001			
16. Manning's roughness coeff., n			.10			
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$	ft/s	Compute V	1.0			
18. Flow length, L	ft		2100'			
19. $T_t = \frac{L}{3600\ V}$	hr	Compute T_t	.58	+		= .58
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr					0.96

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/8

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area # 1

Circle one: T_c T_t through subarea #4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID				
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1)				
3. Flow length, L (total L ≤ 300 ft) ... ft				
4. Two-yr 24-hr rainfall, P_2 ... in				
5. Land slope, s ... ft/ft				
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t ... hr		+		=

Shallow concentrated flow

Segment ID				
7. Surface description (paved or unpaved)				
8. Flow length, L ... ft				
9. Watercourse slope, s ... ft/ft				
10. Average velocity, V (figure 3-1) ... ft/s				
11. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr		+		=

Channel flow

Segment ID	A			
12. Cross sectional flow area, a ... ft^2				
13. Wetted perimeter, p_w ... ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r ... ft				
15. Channel slope, s ... ft/ft	.001			
16. Manning's roughness coeff., n	.10			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V ... ft/s	1.0			
18. Flow length, L ... ft	2250			
19. $T_t = \frac{L}{3600\,V}$ Compute T_t ... hr	.63	+		= .63
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ... hr				.63

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present (Developed)

Drainage Area # 2
Ultimate Development

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1] Table 2-2	CN [1] Fig. 2-3	CN [1] Fig. 2-4	Area ☒ acres ☐ mi^2 ☐ %	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89			20	1840
B	" "	92			25	2350
C	" "	94			30	2850
D	" "	95				
—	IMPERVIOUS AREA Roadways & Rooftops	98			25	2450
—	Ponds	98			6	588
A	WOODS	30				
B	"	55				
C	"	70				
D	"	77				
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82				
D	" "	85				
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75				
C	"	83				
D	"	87				
B	2 Acre Lots	65			20	1300
C	"	77			24	1840
D	"	82			20	1640
					170	14858

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{14858}{170} = 87.4$; $\boxed{87}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area # 2

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only) Segment ID		A		
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1)		.011		
3. Flow length, L (total L ≤ 300 ft)	ft	300'		
4. Two-yr 24-hr rainfall, P_2	in	3.6		
5. Land slope, s	ft/ft	.005		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$ Compute T_t	hr	.08	+	= .08
Shallow concentrated flow Segment ID		B		
7. Surface description (paved or unpaved)		Unpaved		
8. Flow length, L	ft	300'		
9. Watercourse slope, s	ft/ft	.005		
10. Average velocity, V (figure 3-1)	ft/s	1.1		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.08	+	= .08
Channel flow Segment ID		C		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001		
16. Manning's roughness coeff., n		.036		
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	1.44		
18. Flow length, L	ft	650'		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.13	+	= .13
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			.29

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present Developed — Drainage Area # 2

Circle one: T_c T_t through subarea — 3 & 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Unit	Segment ID		
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L ≤ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow	Unit	Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow	Unit	Segment ID A	B	
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft	.001	.001	
16. Manning's roughness coeff., n		.10	.03	
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	1.0	2.7	
18. Flow length, L	ft	3100	2250	
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.43	+ .32	= .95
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.95

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present (Developed)

Drainage Area #3

Ultimate Development

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	Fig. 2-3	Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89			3	267
B	" "	92			30	2760
C	" "	94			35	3290
D	" "	95			37	3515
—	IMPERVIOUS AREA Roadways & Rooftops	98			36	3528
—	Ponds	98			20	1960
A	WOODS	30				
B	"	55				
C	"	70				
D	"	77				
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82				
D	" "	85				
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			6	450
C	"	83				
D	"	87			18	1566
B	2 Acre Lots	65				
C	"	77			5	385
D	"	82				
					190	17721

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{17721}{190} = 93.3$; Use CN = $\boxed{93}$

		Storm #1	Storm #2	Storm #3
Frequency	yr	2	10	25
Rainfall, P (24-hour)	in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project: UPPER MANKLIN CREEK DRAINAGE STUDY By: K.B.E. Date: 11/88

Location: MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present **Developed** Drainage Area # 3

Circle one: **T_t** T_c through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	A		
1.	Surface description (table 3-1)		Impervious		
2.	Manning's roughness coeff., n (table 3-1) ..		.011		
3.	Flow length, L (total L ≤ 300 ft)	ft	300'		
4.	Two-yr 24-hr rainfall, P_2	in	3.6		
5.	Land slope, s	ft/ft	.005		
6.	$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	.08	+	= .08

Shallow concentrated flow

		Segment ID			
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=

Channel flow

		Segment ID	B		
12.	Cross sectional flow area, a	ft^2			
13.	Wetted perimeter, p_w	ft			
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15.	Channel slope, s	ft/ft	.001		
16.	Manning's roughness coeff., n		.03		
17.	$V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	2.7		
18.	Flow length, L	ft	3900		
19.	$T_t = \frac{L}{3600\,V}$ Compute T_t	hr	.40	+	= .40
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			.48

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.B.E. Date 11/88

Location MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked ____ Date ____

Circle one: Present **Developed** Drainage Area # 3

Circle one: T_c **T_t** through subarea 4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID					
1. Surface description (table 3-1)					
2. Manning's roughness coeff., n (table 3-1) ..					
3. Flow length, L (total L ≤ 300 ft)	ft				
4. Two-yr 24-hr rainfall, P_2	in				
5. Land slope, s	ft/ft				
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr		+		=

Shallow concentrated flow

Segment ID					
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+		=

Channel flow

Segment ID		A			
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft	.001			
16. Manning's roughness coeff., n		.10			
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	1.0			
18. Flow length, L	ft	2250			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	.63	+		= .63

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.63

Project UPPER MANKLIN CREEK DRAINAGE STUDY By K.S.E. Date 11/88

Location MD. RT. 90 & MD. RT. 589 WORCESTER COUNTY, MD. Checked ____ Date ____

Circle one: Present (Developed)

Drainage Area # 4
Ultimate Development

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN[1/] Table 2-2	CN Fig. 2-3	CN Fig. 2-4	Area ☒acres ☐mi^2 ☐%	Product of CN x area
A	URBAN DISTRICT Commercial & Business	89				
B	" "	92			15	1380
C	" "	94			13	1222
D	" "	95			17	1615
—	IMPERVIOUS AREA Roadways & Rooftops	98			18	1764
—	Ponds	98				
A	WOODS	30				
B	"	55				
C	"	70				
D	"	77				
A	AGRICULTURAL LANDS Row Crops (SR + CR)	64				
B	" "	75				
C	" "	82				
D	" "	85				
A	RESIDENTIAL DISTRICTS 1/4 Acre Lots	61				
B	"	75			12	900
C	"	83			15	1245
D	"	87			10	870
B	2 Acre Lots	65			5	325
C	"	77			15	1155
D	"	82			20	1640
					140	12116

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{12116}{140} = 86.5$; $\boxed{87}$

	Storm #1	Storm #2	Storm #3
Frequency .... yr	2	10	25
Rainfall, P (24-hour) .... in	3.6	5.6	6.4

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project: UPPER MANKLIN CREEK DRAINAGE STUDY By: K.B.E. Date: 11/88

Location: MD RT. 90 & MD RT. 589 WORCESTER COUNTY, MD Checked: ____ Date: ____

Circle one: Present (Developed) Drainage Area # 4

Circle one: (T_c) T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID		A			
1. Surface description (table 3-1)		Asphalt			
2. Manning's roughness coeff., n (table 3-1)		.011			
3. Flow length, L (total L ≤ 300 ft)	ft	300'			
4. Two-yr 24-hr rainfall, P_2	in	3.6			
5. Land slope, s	ft/ft	.005			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	.08	+		= .08

Shallow concentrated flow

Segment ID		B			
7. Surface description (paved or unpaved)		Paved			
8. Flow length, L	ft	200'			
9. Watercourse slope, s	ft/ft	.005			
10. Average velocity, V (figure 3-1)	ft/s	1.4			
11. $T_t = \frac{L}{3600 V}$ Compute T_t	hr	.04	+		= .04

Channel flow

Segment ID		C		D	
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft	.001		.001	
16. Manning's roughness coeff., n		.10		.10	
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V	ft/s	1.44		1.0	
18. Flow length, L	ft	700		900	
19. $T_t = \frac{L}{3600 V}$ Compute T_t	hr	.14	+	.25	= .39
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr				.51

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:39:52
Watershed File --> C:UMCU11 .WSD Hydrograph File --> C:UMCU11 .HYD

Hydrograph for assumed ultimate conditions.
Two year storm.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
Drainage Area 1	300.00	88.0	1.00	0.50	3.60	2.36	.08	.10
Drainage Area 2	170.00	87.0	0.20	1.00	3.60	2.27	.08	.10
Drainage Area 3	190.00	93.0	0.40	0.75	3.60	2.83	.04	.10
Drainage Area 4	140.00	87.0	0.50	0.00	3.60	2.27	.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 927 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	0.96	0.63	1.00	0.50	No	Computed Ia/p < .1
Drainage Area 2	0.29	0.95	0.20	1.00	No	Computed Ia/p < .1
Drainage Area 3	0.48	0.63	0.40	0.75	No	Computed Ia/p < .1
Drainage Area 4	0.51	0.00	0.50	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:39:52
Watershed File --> C:UMCU11 .WSD Hydrograph File --> C:UMCU11 .HYD

Hydrograph for assumed ultimate conditions.
Two year storm.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	344	13.2
Drainage Area 2	249	13.2
Drainage Area 3	330	13.0
Drainage Area 4	263	12.4
Composite Watershed	927	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:39:52
Watershed File --> C:UMCU11 .WSD Hydrograph File --> C:UMCU11 .HYD

Hydrograph for assumed ultimate conditions.
Two year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	9	11	14	20	22	24	28	33	42
Drainage Area 2	5	7	8	11	13	14	16	18	21
Drainage Area 3	8	11	14	20	22	25	29	38	55
Drainage Area 4	8	11	16	28	47	84	153	232	263
Total (cfs)	30	40	52	79	104	147	226	321	381

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	59	86	126	176	280	344	332	278	216
Drainage Area 2	27	37	61	101	203	249	213	148	95
Drainage Area 3	89	143	211	274	330	286	206	138	94
Drainage Area 4	252	200	147	112	70	48	37	30	26
Total (cfs)	427	466	545	663	883	927	788	594	431

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:39:52
Watershed File --> C:UMCU11 .WSD Hydrograph File --> C:UMCU11 .HYD

Hydrograph for assumed ultimate conditions.
Two year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	165	113	82	59	44	37	32	28	25
Drainage Area 2	63	41	32	25	21	19	17	14	13
Drainage Area 3	68	50	40	33	28	25	22	19	18
Drainage Area 4	23	20	18	16	14	13	11	10	10
Total (cfs)	319	224	172	133	107	94	82	71	66

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	23	20	18	13	1
Drainage Area 2	12	11	10	7	0
Drainage Area 3	17	15	13	10	0
Drainage Area 4	9	8	7	6	0
Total (cfs)	61	54	48	36	1

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:39:52
Watershed File --> C:UMCU11 .WSD Hydrograph File --> C:UMCU11 .HYD

Hydrograph for assumed ultimate conditions.
Two year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	30	14.8	152
11.1	33	14.9	143
11.2	37	15.0	133
11.3	40	15.1	128
11.4	44	15.2	123
11.5	48	15.3	117
11.6	52	15.4	112
11.7	61	15.5	107
11.8	70	15.6	104
11.9	79	15.7	102
12.0	104	15.8	99
12.1	147	15.9	97
12.2	226	16.0	94
12.3	321	16.1	92
12.4	381	16.2	89
12.5	427	16.3	87
12.6	466	16.4	84
12.7	545	16.5	82
12.8	663	16.6	80
12.9	773	16.7	78
13.0	883	16.8	75
13.1	905	16.9	73
13.2	927	17.0	71
13.3	857	17.1	70
13.4	788	17.2	69
13.5	691	17.3	68
13.6	594	17.4	67
13.7	512	17.5	66
13.8	431	17.6	65
13.9	375	17.7	64
14.0	319	17.8	63
14.1	287	17.9	62
14.2	256	18.0	61
14.3	224	18.1	60
14.4	207	18.2	60
14.5	189	18.3	59
14.6	172	18.4	58
14.7	162	18.5	58

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:39:52
shed File --> C:UMCU11 .WSD Hydrograph File --> C:UMCU11 .HYD

Hydrograph for assumed ultimate conditions.
Two year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	57	22.4	33
18.7	56	22.5	32
18.8	55	22.6	31
18.9	55	22.7	30
19.0	54	22.8	29
19.1	53	22.9	28
19.2	53	23.0	27
19.3	52	23.1	26
19.4	52	23.2	26
19.5	51	23.3	25
19.6	50	23.4	24
19.7	50	23.5	23
19.8	49	23.6	22
19.9	49	23.7	21
20.0	48	23.8	20
20.1	47	23.9	19
20.2	47	24.0	19
20.3	46	24.1	18
20.4	46	24.2	17
20.5	45	24.3	16
20.6	44	24.4	15
20.7	44	24.5	14
20.8	43	24.6	13
20.9	43	24.7	12
21.0	42	24.8	12
21.1	41	24.9	11
21.2	41	25.0	10
21.3	40	25.1	9
21.4	40	25.2	8
21.5	39	25.3	7
21.6	38	25.4	6
21.7	38	25.5	5
21.8	37	25.6	5
21.9	37	25.7	4
22.0	36	25.8	3
22.1	35	25.9	2
22.2	34		
22.3	33		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:40:56
Watershed File --> C:UMCU12 .WSD Hydrograph File --> C:UMCU12 .HYD

Hydrograph for assumed ultimate conditions.
Ten year storm.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
Drainage Area 1	300.00	88.0	1.00	0.50	5.60	4.24	.05	.10
Drainage Area 2	170.00	87.0	0.20	1.00	5.60	4.14	.05	.10
Drainage Area 3	190.00	93.0	0.40	0.75	5.60	4.79	.03	.10
Drainage Area 4	140.00	87.0	0.50	0.00	5.60	4.14	.05	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 1644 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	0.96	0.63	1.00	0.50	No	Computed Ia/p < .1
Drainage Area 2	0.29	0.95	0.20	1.00	No	Computed Ia/p < .1
Drainage Area 3	0.48	0.63	0.40	0.75	No	Computed Ia/p < .1
Drainage Area 4	0.51	0.00	0.50	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:40:56
Watershed File --> C:UMCU12 .WSD Hydrograph File --> C:UMCU12 .HYD

Hydrograph for assumed ultimate conditions.
Ten year storm.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	618	13.2
Drainage Area 2	454	13.2
Drainage Area 3	559	13.0
Drainage Area 4	479	12.4
Composite Watershed	1644	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:40:56
Watershed File --> C:UMCU12 .WSD Hydrograph File --> C:UMCU12 .HYD

Hydrograph for assumed ultimate conditions.
Ten year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	16	20	26	36	40	44	50	60	76
Drainage Area 2	10	12	15	21	23	26	29	33	38
Drainage Area 3	14	18	24	34	37	43	50	64	92
Drainage Area 4	15	21	29	52	85	154	279	423	479
Total (cfs)	55	71	94	143	185	267	408	580	685

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	105	155	227	316	503	618	596	499	388
Drainage Area 2	48	68	111	184	371	454	388	269	173
Drainage Area 3	151	242	357	464	559	485	348	233	159
Drainage Area 4	459	364	269	205	127	87	67	55	48
Total (cfs)	763	829	964	1169	1560	1644	1399	1056	768

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:40:56
Watershed File --> C:UMCU12 .WSD Hydrograph File --> C:UMCU12 .HYD

Hydrograph for assumed ultimate conditions.
Ten year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	296	203	147	105	79	66	58	50	46
Drainage Area 2	114	75	58	46	38	34	31	26	24
Drainage Area 3	115	84	68	55	47	43	37	33	30
Drainage Area 4	43	37	33	29	26	24	21	19	18
Total (cfs)	568	399	306	235	190	167	147	128	118

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	42	36	32	24	2
Drainage Area 2	22	20	18	13	0
Drainage Area 3	28	26	21	17	0
Drainage Area 4	17	14	13	11	0
Total (cfs)	109	96	84	65	2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:40:56
Watershed File --> C:UMCU12 .WSD Hydrograph File --> C:UMCU12 .HYD

Hydrograph for assumed ultimate conditions.
Ten year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	55	14.8	270
11.1	60	14.9	253
11.2	66	15.0	235
11.3	71	15.1	226
11.4	79	15.2	217
11.5	86	15.3	208
11.6	94	15.4	199
11.7	110	15.5	190
11.8	127	15.6	185
11.9	143	15.7	181
12.0	185	15.8	176
12.1	267	15.9	172
12.2	408	16.0	167
12.3	580	16.1	163
12.4	685	16.2	159
12.5	763	16.3	155
12.6	829	16.4	151
12.7	964	16.5	147
12.8	1169	16.6	143
12.9	1365	16.7	139
13.0	1560	16.8	136
13.1	1602	16.9	132
13.2	1644	17.0	128
13.3	1521	17.1	126
13.4	1399	17.2	124
13.5	1228	17.3	122
13.6	1056	17.4	120
13.7	912	17.5	118
13.8	768	17.6	116
13.9	668	17.7	114
14.0	568	17.8	113
14.1	512	17.9	111
14.2	455	18.0	109
14.3	399	18.1	108
14.4	368	18.2	106
14.5	337	18.3	105
14.6	306	18.4	104
14.7	288	18.5	103

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:40:56

Watershed File --> C:UMCU12 .WSD Hydrograph File --> C:UMCU12 .HYD

Hydrograph for assumed ultimate conditions.
Ten year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	101	22.4	59
18.7	100	22.5	57
18.8	99	22.6	56
18.9	97	22.7	54
19.0	96	22.8	52
19.1	95	22.9	51
19.2	94	23.0	49
19.3	92	23.1	48
19.4	91	23.2	46
19.5	90	23.3	45
19.6	89	23.4	43
19.7	88	23.5	41
19.8	86	23.6	40
19.9	85	23.7	38
20.0	84	23.8	37
20.1	83	23.9	35
20.2	82	24.0	34
20.3	81	24.1	32
20.4	80	24.2	30
20.5	79	24.3	29
20.6	78	24.4	27
20.7	77	24.5	26
20.8	76	24.6	24
20.9	75	24.7	22
21.0	75	24.8	21
21.1	74	24.9	19
21.2	73	25.0	18
21.3	72	25.1	16
21.4	71	25.2	15
21.5	70	25.3	13
21.6	69	25.4	11
21.7	68	25.5	10
21.8	67	25.6	8
21.9	66	25.7	7
22.0	65	25.8	5
22.1	63	25.9	4
22.2	62		
22.3	60		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:46:41
Watershed File --> C:UMCU13 .WSD Hydrograph File --> C:UMCU13 .HYD

Hydrograph for assumed ultimate conditions.
Twenty -five year storm.

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
Drainage Area 1	300.00	88.0	1.00	0.50	6.40	5.01	.04	.10
Drainage Area 2	170.00	87.0	0.20	1.00	6.40	4.90	.05	.10
Drainage Area 3	190.00	93.0	0.40	0.75	6.40	5.58	.02	.10
Drainage Area 4	140.00	87.0	0.50	0.00	6.40	4.90	.05	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 800.00 acres or 1.2500 sq.mi
Peak discharge = 1936 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
Drainage Area 1	0.96	0.63	1.00	0.50	No	Computed Ia/p < .1
Drainage Area 2	0.29	0.95	0.20	1.00	No	Computed Ia/p < .1
Drainage Area 3	0.48	0.63	0.40	0.75	No	Computed Ia/p < .1
Drainage Area 4	0.51	0.00	0.50	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:46:41
Watershed File --> C:UMCU13 .WSD Hydrograph File --> C:UMCU13 .HYD

Hydrograph for assumed ultimate conditions.
Twenty -five year storm.

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge (cfs)	Time to Peak at Composite Outfall (hrs)
Drainage Area 1	730	13.2
Drainage Area 2	538	13.2
Drainage Area 3	651	13.0
Drainage Area 4	567	12.4
Composite Watershed	1936	13.2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:46:41
Watershed File --> C:UMCU13 .WSD Hydrograph File --> C:UMCU13 .HYD

Hydrograph for assumed ultimate conditions.
Twenty -five year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
Drainage Area 1	19	23	31	42	47	52	59	70	89
Drainage Area 2	12	14	18	25	27	31	34	39	46
Drainage Area 3	17	22	28	40	43	50	58	75	108
Drainage Area 4	18	25	34	61	101	182	330	501	567
Total (cfs)	66	84	111	168	218	315	481	685	810

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
Drainage Area 1	124	183	268	373	594	730	705	589	458
Drainage Area 2	57	81	131	217	439	538	459	319	204
Drainage Area 3	176	282	416	540	651	565	406	272	186
Drainage Area 4	543	431	318	242	150	103	79	65	57
Total (cfs)	900	977	1133	1372	1834	1936	1649	1245	905

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:46:41
Watershed File --> C:UMCU13 .WSD Hydrograph File --> C:UMCU13 .HYD

Hydrograph for assumed ultimate conditions.
Twenty -five year storm.

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
Drainage Area 1	350	240	174	124	94	77	68	59	54
Drainage Area 2	135	89	69	55	46	40	36	31	29
Drainage Area 3	134	98	80	65	55	50	43	38	35
Drainage Area 4	50	44	39	34	31	28	25	23	21
Total (cfs)	669	471	362	278	226	195	172	151	139

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
Drainage Area 1	49	42	38	28	2
Drainage Area 2	26	23	21	16	0
Drainage Area 3	33	30	25	20	0
Drainage Area 4	20	17	15	13	0
Total (cfs)	128	112	99	77	2

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:46:41
Watershed File --> C:UMCU13 .WSD Hydrograph File --> C:UMCU13 .HYD

Hydrograph for assumed ultimate conditions.
Twenty -five year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	66	14.8	320
11.1	72	14.9	299
11.2	78	15.0	278
11.3	84	15.1	268
11.4	93	15.2	257
11.5	102	15.3	247
11.6	111	15.4	236
11.7	130	15.5	226
11.8	149	15.6	220
11.9	168	15.7	214
12.0	218	15.8	207
12.1	315	15.9	201
12.2	481	16.0	195
12.3	685	16.1	190
12.4	810	16.2	186
12.5	900	16.3	181
12.6	977	16.4	177
12.7	1133	16.5	172
12.8	1372	16.6	168
12.9	1603	16.7	164
13.0	1834	16.8	159
13.1	1885	16.9	155
13.2	1936	17.0	151
13.3	1792	17.1	149
13.4	1649	17.2	146
13.5	1447	17.3	144
13.6	1245	17.4	141
13.7	1075	17.5	139
13.8	905	17.6	137
13.9	787	17.7	135
14.0	669	17.8	132
14.1	603	17.9	130
14.2	537	18.0	128
14.3	471	18.1	126
14.4	435	18.2	125
14.5	398	18.3	123
14.6	362	18.4	122
14.7	341	18.5	120

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 11-21-1988 09:46:41
Watershed File --> C:UMCU13 .WSD Hydrograph File --> C:UMCU13 .HYD

Hydrograph for assumed ultimate conditions.
Twenty -five year storm.

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	118	22.4	70
18.7	117	22.5	68
18.8	115	22.6	66
18.9	114	22.7	64
19.0	112	22.8	62
19.1	111	22.9	60
19.2	109	23.0	58
19.3	108	23.1	56
19.4	107	23.2	55
19.5	106	23.3	53
19.6	104	23.4	51
19.7	103	23.5	49
19.8	102	23.6	47
19.9	100	23.7	45
20.0	99	23.8	43
20.1	98	23.9	41
20.2	97	24.0	40
20.3	96	24.1	38
20.4	95	24.2	36
20.5	94	24.3	34
20.6	92	24.4	32
20.7	91	24.5	30
20.8	90	24.6	28
20.9	89	24.7	26
21.0	88	24.8	25
21.1	87	24.9	23
21.2	86	25.0	21
21.3	85	25.1	19
21.4	84	25.2	17
21.5	83	25.3	15
21.6	81	25.4	13
21.7	80	25.5	11
21.8	79	25.6	10
21.9	78	25.7	8
22.0	77	25.8	6
22.1	75	25.9	4
22.2	73		
22.3	71		

APPENDIX 2, SECTION 4

POND-2 Version: S/N:

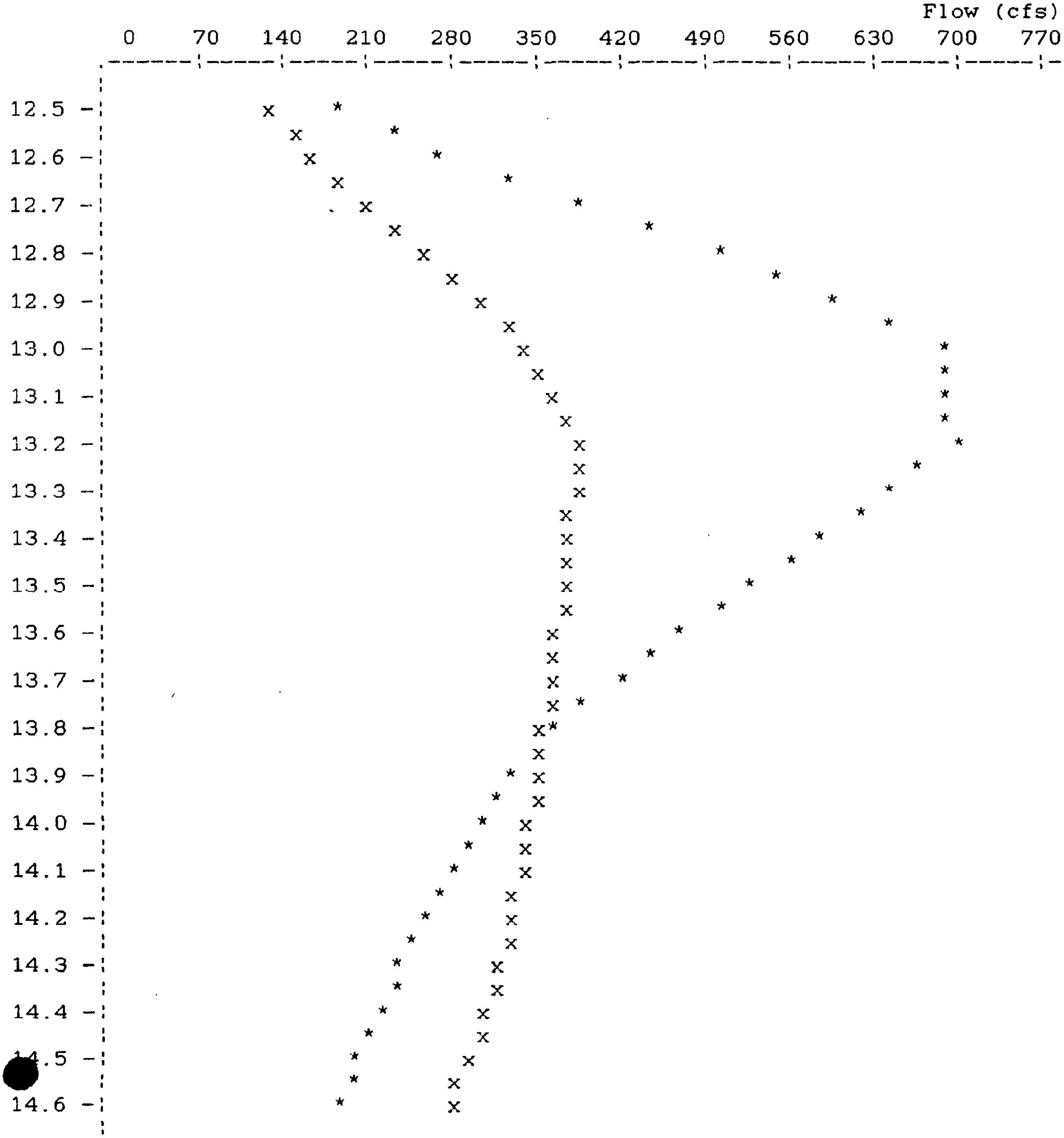
>>>>> HYDROGRAPH OVERLAY OPTION <<<<<

11-21-1988 10:26:13

Inflow Hydrograph: C:UMCF11 .HYD Qpeak = 695.0 cfs
Overlay Hydrograph: C:UMCE11 .HYD Qpeak = 381.0 cfs

Approximate Storage Volume
(computed from t= 11.10 to 13.84 hrs)

23.5 acre-ft



TIME
(hrs) * Inflow Hydrograph ---> C:UMCF11 .HYD Qmax = 695.0 cfs
x Overlay Hydrograph ---> C:UMCE11 .HYD Qmax = 381.0 cfs

POND-2 Version: S/N:

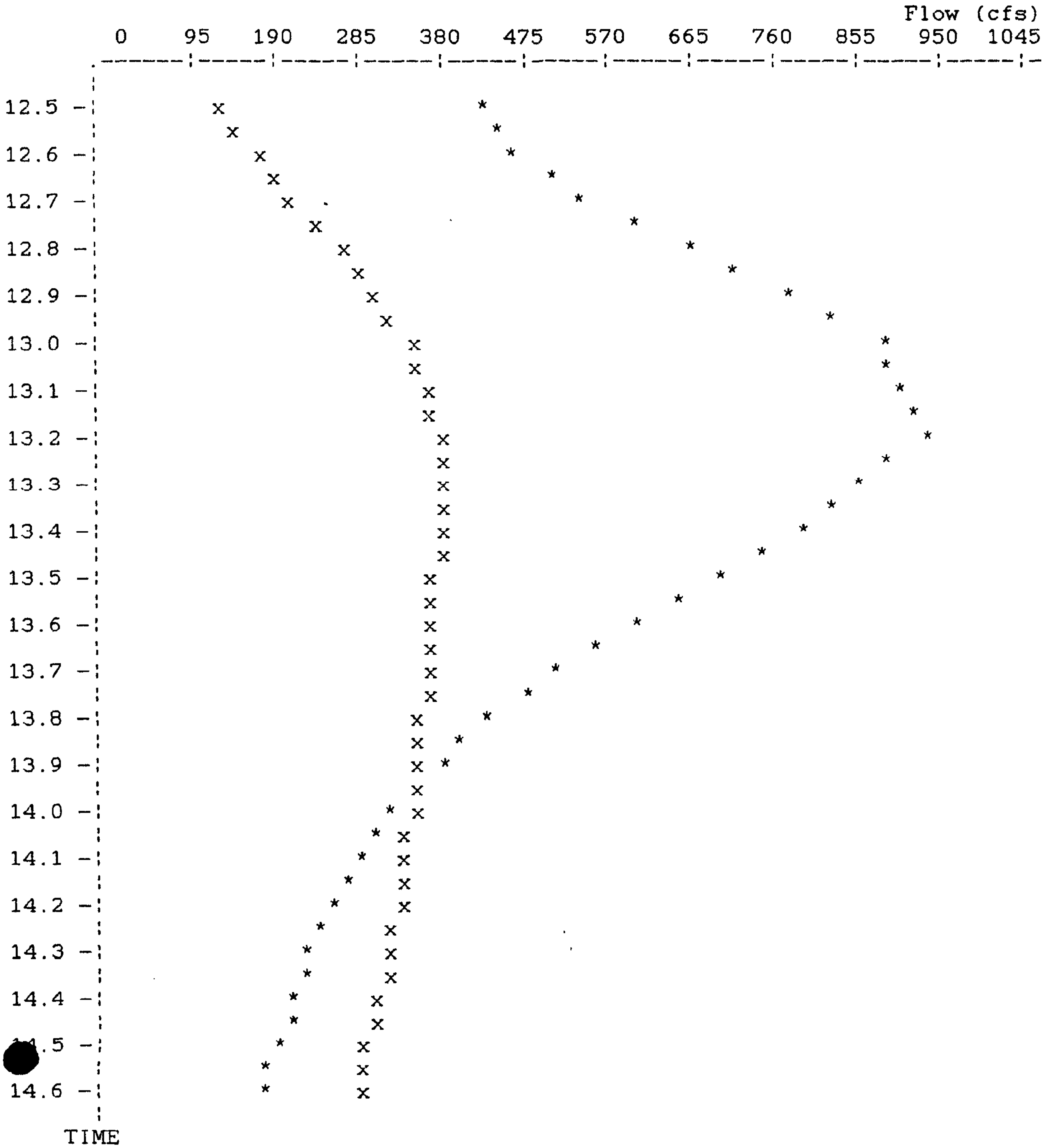
>>>>> HYDROGRAPH OVERLAY OPTION <<<<<

11-21-1988   10:26:51

Inflow Hydrograph: C:UMCU11 .HYD   Qpeak = 927.0 cfs
Overlay Hydrograph: C:UMCE11 .HYD   Qpeak = 381.0 cfs

Approximate Storage Volume
(computed from t= 11.10 to 13.95 hrs)

51.7 acre-ft



* Inflow Hydrograph ---> C:UMCU11 .HYD   Qmax = 927.0 cfs
x Overlay Hydrograph ---> C:UMCE11 .HYD   Qmax = 381.0 cfs

POND-2 Version: S/N:

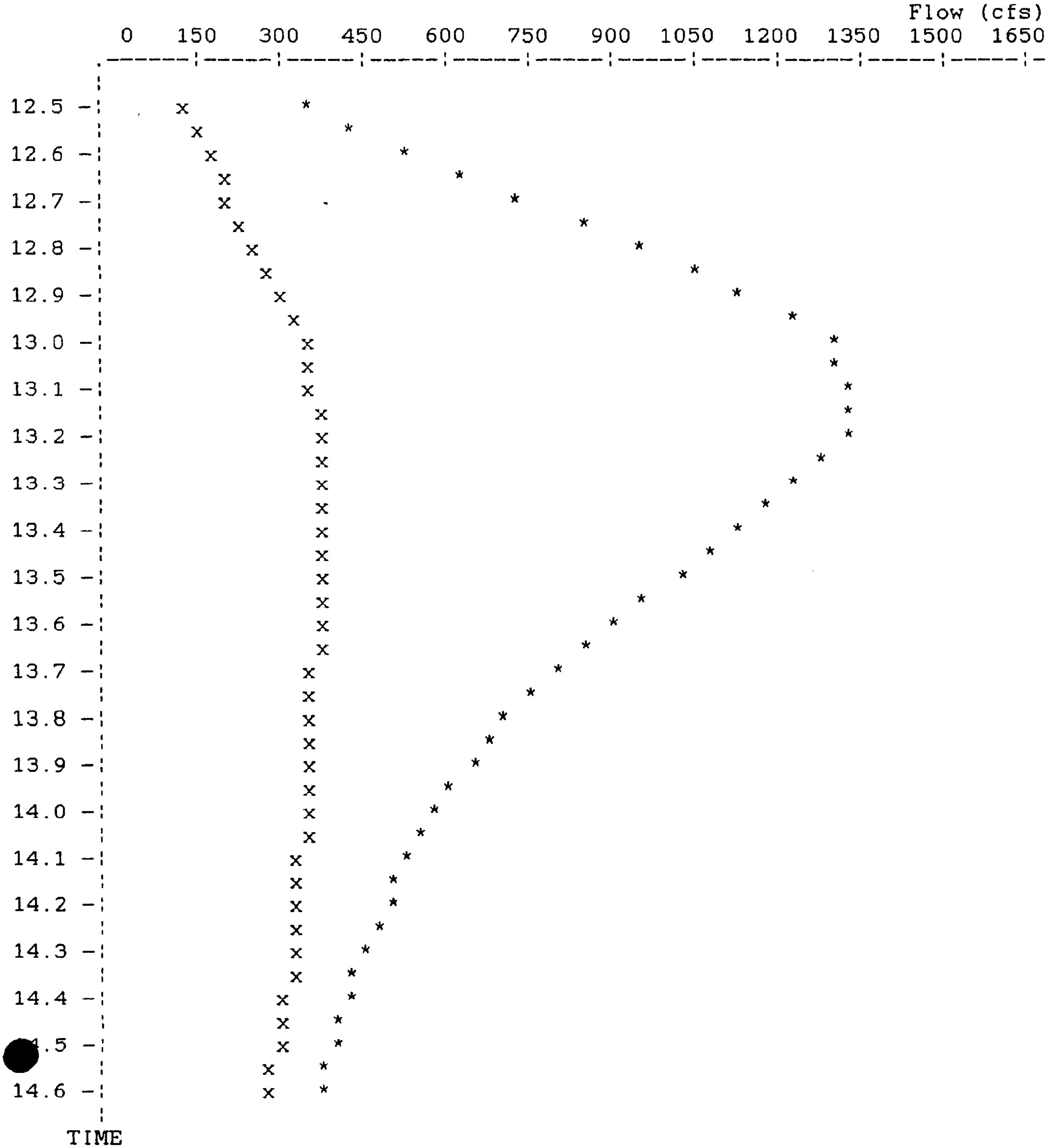
>>>>> HYDROGRAPH OVERLAY OPTION <<<<<

11-21-1988 10:28:16

Inflow Hydrograph: C:UMCF12 .HYD Qpeak = 1331.0 cfs
Overlay Hydrograph: C:UMCE11 .HYD Qpeak = 381.0 cfs

Approximate Storage Volume
(computed from t= 11.10 to 25.80 hrs)

125.5 acre-ft



* Inflow Hydrograph ---> C:UMCF12 .HYD Qmax = 1331.0 cfs
x Overlay Hydrograph ---> C:UMCE11 .HYD Qmax = 381.0 cfs

POND-2 Version: S/N:

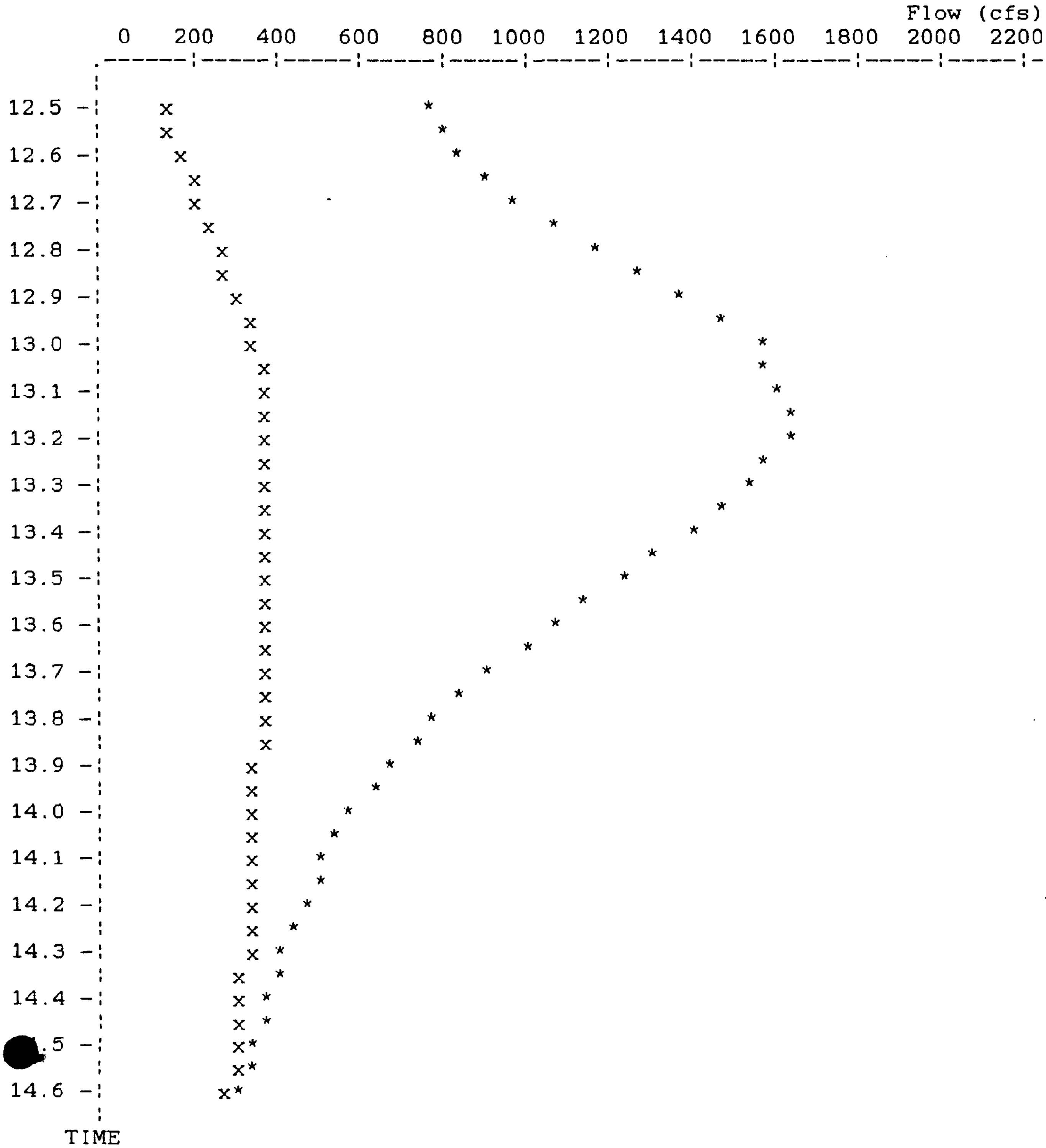
>>>>> HYDROGRAPH OVERLAY OPTION <<<<<

11-21-1988 10:28:48

Inflow Hydrograph: C:UMCU12 .HYD Qpeak = 1644.0 cfs
Overlay Hydrograph: C:UMCE11 .HYD Qpeak = 381.0 cfs

Approximate Storage Volume
(computed from t= 11.10 to 25.30 hrs)

164.7 acre-ft



* Inflow Hydrograph ---> C:UMCU12 .HYD Qmax = 1644.0 cfs
x Overlay Hydrograph ---> C:UMCE11 .HYD Qmax = 381.0 cfs